DOCUMENT RESUME

ED 303 271 PS 017 791

AUTHOR Prawat, Richard S.
TITLE Promoting Access: The Role of Organization and Awareness Factors. Elementary Subjects Center Series No. 1.
INSTITUTION Center for the Learning and Teaching of Elementary Subjects, East Lansing, MI.
SPONS AGENCY Office of Educational Research and Improvement (ED), Washington, D.C.
PUB DATE Dec 88
CONTRACT G0098C0226
NOTE 94p.
AVAILABLE FROM Institute for Research on Teaching, College of Education, Michigan State University, 252 Erickson Hall, East Lansing, MI 48824 ($8.50).
PUB TYPE Information Analyses (070) -- Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS *Cognitive Processes; *Cognitive Structures; Educational Practices; Elementary Education; Guidelines; *Learning Strategies; *Perception; Student Characteristics; Teaching Methods; *Transfer of Training
IDENTIFIERS *Dispositions; *Knowledge Base (Students); Knowledge Utilization; Reflective Awareness; Reflective Thinking

ABSTRACT

This review presents a framework that accommodates static and dynamic approaches to comprehension of students' transfer of knowledge and skill. The review focuses on three sets of variables considered fundamental to students' ability to access intellectual resources in potentially relevant situations: knowledge bases, strategies, and dispositions. It is argued that for all three categories of variables, the factors of cognitive organization and reflective awareness determine the extent to which individuals are able to use their intellectual resources. In the knowledge base category, the key organizational factor is the elaborateness of connections between units of knowledge. In the strategic category, the major organizational issue is the trade-off between general versus more specific strategies. Awareness, denoted as "metacognition" here, is one of the most important factors influencing transfer. In the dispositions category, discussion of performance and mastery dispositions suggests that organization and awareness factors interact to influence dispositional thinking. Concluding remarks discuss ways in which teachers can attend to these factors to help students better use intellectual resources. Approximately 175 references are cited. (RH)

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Elementary Subjects Center
Series No. 1

PROMOTING ACCESS: THE ROLE OF ORGANIZATION AND AWARENESS FACTORS

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Published by

The Center for the Learning and Teaching of Elementary Subjects

Institute for Research on Teaching
252 Erickson Hall
Michigan State University
East Lansing, Michigan 48824-1034

December 1988

This work is sponsored in part by the Center for the Learning and Teaching of Elementary Subjects, Institute for Research on Teaching, Michigan State University. The Center for the Learning and Teaching of Elementary Subjects is funded primarily by the Office of Educational Research and Improvement, U.S. Department of Education. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the Office or Department (Cooperative Agreement No. G0098C0226).

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Abstract

The emphasis in this paper is on access, a variable which reflects the extent to which students are able to draw on or utilize their intellectual resources in potentially relevant situations. Several bodies of research are employed in developing the following argument: Two important factors influence students' ability to access knowledge, strategy, and disposition. The first is organizational in nature, the second relates to the amount of reflective awareness possessed by the individual. This paper discusses how organization and awareness factors influence access in each of the informational categories and how teachers can better attend to these factors and thus promote access or transfer in students.

PROMOTING ACCESS: THE ROLE OF ORGANIZATION AND AWARENESS FACTORS

Richard S. Prawat[1]

Promoting the transfer of knowledge and skill in students is a major--many would say the major--goal of education. Brown, Bransford, Ferrara, and Campione (1983) illustrate the importance of transfer by pointing out that most people would be reluctant to say that students had learned elementary mathematics if they could only solve the problems they had practiced in class. For this reason, transfer--the ability to draw on or access one's intellectual resources in situations where those resources may be relevant--has been a central topic in research on learning and instruction. This is even more true today because current views of learning blur the distinction between knowledge acquisition and knowledge utilization. Voss (1987), for one, maintains that the concept of learning is subordinate to that of transfer because knowledge acquisition must involve the utilization of prior knowledge. New information is always interpreted in terms of what one already knows.

Given its practical and theoretical significance, it is surprising how little consensus there is about how best to facilitate transfer. There is even disagreement about what counts as a transferable product. Earlier views of transfer tended to focus almost exclusively on the knowledge base--that is, on the extent to which knowledge acquired in one context might generalize to other contexts. Brown et al. (1983) term this the "static" approach to transfer.

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Like a snapshot, it attempts to characterize what an individual knows at a particular point in time.

The static approach contrasts with a more dynamic approach to transfer that addresses a different type of question: What strategies does the individual utilize in moving from a state of not knowing to one of knowing? In this second approach, the focus is less on the person's current state of knowledge and more on how the person behaves when he or she doesn't understand something. The dynamic approach to transfer thus emphasizes knowledge acquisition skills. Being able to monitor how well one comprehends new and difficult text is an example of a such a skill. One advantage to the dynamic approach is that it allows researchers to take into account important strategic and motivational variables. These variables affect learning and also generalize from one situation to another (Dweck & Elliott, 1983).

Because static and dynamic approaches to transfer appear equally valid, it is important that we develop a view of transfer that accommodates both perspectives. The purpose of this paper is to present a framework that can serve this purpose. In this framework, three sets of variables are considered--knowledge base, strategic, and dispositional. Each is complex. Included in the knowledge base category, for example, are several overlapping but distinguishable types of knowledge: formal and informal knowledge, conceptual and procedural knowledge, and concrete or representational knowledge. Because these terms are defined in various ways, some explication of what is meant by each is in order.

The first two sets of terms are primarily contrastive in nature. The distinction between formal and informal knowledge illustrates this. As Resnick (1987) points out, this distinction often is viewed as being synomous with that between "instructed" and "constructed" knowledge; this, however, may be an oversimplification. Informal or intuitive knowledge does represent an individual's

often imaginative efforts to construct meaning from everyday experience; it is idiosyncratic and may directly contradict the more formal knowledge acquired in the classroom. However, as Resnick (1987) indicates, formal knowledge also represents a construction--albeit a more constrained one. It is more constrained in at least two ways. First, to use Piaget's (1964) expression, it is "provoked" by certain types of experiences. It develops out of the child's interaction with school curricula. In the absence of exposure to this sort of experience, formal knowledge probably would not develop.

There is an accountability dimension to formal knowledge as well. It can be judged relative to certain disciplinary standards. Thus, formal knowledge should be consistent with the body of disciplinary knowledge that underlies various school subjects. As Resnick (1987) puts it, formal knowledge is "constrained by the principles that govern a domain" (p. 47). This is not to imply that the codified set of principles and propositions that form the core of a discipline is static. Cobb, Yackel, and Wood (1988) remind us that disciplinary knowledge "is continually regenerated and modified by the coordinated actions of members of a community" (p. 13). It is a socially constructed product. Scholars in a field may disagree about the essential nature of this product--although this is more likely in some disciplines then in others (Phillips & Soltis, 1985). Fortunately, given this disagreement, disciplines also have their ways of evaluating knowledge claims. Thus, students need not rely upon authority in deciding what to believe. They can employ techniques developed by the discipline to test their ideas. These modes of verification are independent of the uses to which the knowledge is put.

A distinction between conceptual and procedural knowledge is frequently made in the literature (Hiebert & Wearne, 1986). Conceptual knowledge is knowledge <u>that</u> something is the case, while procedural knowledge is more mechanical,

more concerned with the carrying out of some action. Procedural knowledge can be acquired through rote memorization (Hiebert & Lefevre, 1986). An example in the area of mathematics is provided by Nesher (1986). An understanding of the concept of average or mean entails knowing a number of things: that it is a number representing a set of numbers, that it cannot fall outside the range of numbers given, that it need not be one of those numbers, and so forth. Somewhat independent of this conceptual knowledge is the procedural knowledge that allows one to actually compute a mean (i.e., adding scores and dividing by the number of scores in the set). An emphasis on procedural knowledge frequently predominates in mathematics, at least at the elementary level (Porter, Floden, Freeman, Schmidt, & Schwille, 1986), and this may be true of other subject matter domains as well (Weiss, 1978).

Representations are embodiments or interpretations of ideas. As such, they can be verbal, pictorial or diagrammatic, or physical. They play an important role in learning and instruction. Representations have been used as aids in solving problems, for example. Concrete materials often allow children to "act out" and thus understand textbook word problems that they otherwise might find confusing (Lesh, Post, & Behr, 1987). They can give meaning to an abstract concept by highlighting certain properties of the concept. In the form of analogies and metaphors, they may allow learners to transfer knowledge from one domain to another.

As will be explained later, the term strategy is meant to include a broad range of routines; included under the strategy rubric are various heuristic techniques, such as those identified by Schoenfeld (1985) in mathematics, as well as the more inclusive, executive control functions described by Brown and her colleagues (Brown et al., 1983). This latter type strategy (e.g., planning, monitoring, checking, and revising), although not viewed as

content-independent, is similar across various domains of application. In reading, for example, monitoring understanding of a particular segment of text might involve attempts to summarize the content; a comparable strategy, applied to mathematics, might entail drawing a sketch to test one's understanding of a problem statement.

The final category of variable dealt with in this paper is the most difficult to define. Dispositions have been characterized as "habits of mind" (Katz & Raths, 1985). As such, they are thought to influence how individuals approach or deal with various situations--for example, achievement situations. They are viewed as necessary because of the frequent disparity between what individuals are capable of doing in an ideal situation and what they actually do in a more normal context (Dweck & Elliott, 1983. Dispositions, particularly motivational dispositions, are thought to account for much of this disparity. Thus, there is evidence to show that children differ dramatically in their orientations toward learning (Dweck & Elliott, 1983).

The two orientations that have been identified are termed "mastery" and "performance" orientations. Children who evidence the former approach learning tasks with an open mind, asking questions such as "What will I learn?" as opposed to the more defensive "Will I look smart?" Looking smart is more important for performance-oriented children, who tend to avoid difficult learning tasks and are apt to withdraw when obstacles to learning are confronted. Fortunately, dispositions are not inherited traits; they can be cultivated in students to a greater or lesser degree.

This paper pulls together several research strands in developing the following argument: Across the three major categories of informational variables--knowledge base, strategic, and dispositional--two factors determine the extent to which individuals are able to access or utilize their intellectual

resources. The first can be characterized as organizational in nature, the second relates to the amount of reflective awareness possessed by the individual. These two factors interact, both within and between each category of variable. Within the knowledge base category, for example, a case will be made for the role that reflective awareness plays in getting individuals to reorganize or restructure their knowledge. As an example of interaction between different types of variables, there is research indicating that certain executive control strategies, such as comprehension fostering, are much more dependent on prior knowledge than others, such as comprehension monitoring (Hasselhorn & Korkel, 1986). In a similar fashion, some motivational dispositions appear to be more tightly linked to certain strategies than others. These and other examples of interaction will be elaborated on in various sections of the paper.

A number of cognitive psychologists have highlighted the importance of access as it relates to knowledge and strategy. Bransford, Sherwood, Vye, and Rieser (1986) cite studies on problem solving that demonstrate the pervasiveness of "access failure" as a cause of poor performance: "The fact that people have acquired knowledge that is relevant to a particular situation provides no guarantee that access will occur" (p. 1080). Schoenfeld (1985) seconds this notion. In mathematical problem solving, he argues, "The issue for students is often not how efficiently they will use the relevant resources potentially at their disposal. It is whether they will allow themselves access to those resources at all" (p. 13).

The insistence that knowledge, strategy, and disposition be accessible is a stringent criterion for both psychologists and educators. It recognizes that the acquisition of information in each of these categories is not the only, or even main, issue in education. At least as important is the problem of getting

students to access or draw on this information in contexts where it is potentially relevant. Pressley, Goodchild, Fleet, Zejchowski, and Evans (in press), in talking about strategic thinking, define this as the problem of "durability," a concern that they say unites teachers, theorists, and researchers: How can we promote the maintenance and utilization of cognitive strategies on the part of students?

Organization and awareness factors influence the accessibility of each major category of variable. Each factor assumes a slightly different character, however, depending upon whether knowledge, skill, or disposition is involved. In the knowledge base category, the key organizational factor is the elaborateness or richness of connections between units of knowledge (Chi & Koeske, 1983). The ability to access knowledge varies dramatically as a function of how well linked the knowledge is. Possessing knowledge is not enough, however, even if that knowledge is well organized. It is equally important that one be aware of what one knows; without this awareness, the knowledge is relatively "inert" (Bransford et al., 1986). Teachers can foster reflective awareness by encouraging students to talk and write about what they are learning.

At the strategic level, the major organizational issue is the trade-off between general versus more specific strategies. Specific strategies are more teachable but can only be applied in a limited number of contexts, while general strategies are more versatile but are also viewed as more difficult to teach. At this level, awareness, in the guise of "metacognition," is considered one of the most important factors influencing transfer.

At the dispositional level, organization and awareness factors reappear in altered form but continue to play a key role in accessibility. Research discussed in the last section of the paper supports the claim that, organizationally, dispositions are closely tied to strategies. This research indicates

that organization and awareness factors interact: The tendency to think about one's strategic action at a more goal-oriented, dispositional level is strongly influenced by how effectively one can maintain action at a strategic level. It is when an act (e.g., comprehension monitoring) is mastered at the strategic level that more abstract or dispositional ways of characterizing the act begin to emerge (e.g., becoming more knowledgeable about the subjects one is studying).

The remainder of the paper will discuss how organization and awareness factors influence student access to potentially relevant knowledge, strategy, and disposition; also addressed will be some possible ways that teachers can attend to these factors and thus ensure that students make better use of their own intellectual resources.

Knowledge Base

Organization

The focus in this section is on knowledge as it may exist in the learner's head, and how its acquisition and utilization is affected by organizational factors. The importance of this set of factors has long been recognized. George Polya (1973), for example, goes so far as to say that good organization is even more important than the extent of one's knowledge. Research on expertise highlights the importance of knowledge structure or organization; a major source of the difference between experts and novices is the way the former are able to organize their knowledge in a domain so that it can be used efficiently and effectively (Sternberg, 1981). Experts know more than novices, but they also are able to make better use of what they know by organizing it in a more coherent fashion. Experts may make greater use than novices of middle-range concepts or understandings in connecting abstract general ideas with factual detail. Thus,

experts are said to possess "multilevel" knowledge structures (Bereiter & Scardamalia, 1986); presumably, middle-range "key ideas" play a major role in this regard.

Key ideas. Not all ideas in a domain are created equal. As Bruner (1960) put it over a quarter century ago, "The basic ideas that lie at the heart of all science and mathematics and the basic themes that give form to life and literature are as simple as they are powerful." Some ideas are more meaningful than others--which is to say, they allow for a richer set of connections. In a sense, these key ideas or understandings serve as anchors for the cognitive structure. Many of these key ideas are just now being identified in domains such as mathematics (Lampert, 1986; Resnick & Omanson, 1987) and science (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1981; Larkin, 1981).

This may sound surprising, given the amount of work that has been done in the last century to explicate the foundations of mathematics and science. However, as von Glasersfeld (1987) points out, this work has been mostly definitional in nature, and thus is formal rather than conceptual. In mathematics, this work involves substituting "other signs or symbols for the definiendum. Rarely, if ever," von Glasersfeld adds, "is there a hint, let alone an indication, of what one must do in order to build up the conceptual structures that are to be associated with the symbols" (pp. 13-14). This, of course, is exactly the task confronted by the child as he or she seeks to acquire a new concept. Thus, the type of conceptual analysis called for by von Glasersfeld and others in mathematics would simultaneously take into account the structure of the discipline and the cognitive structure of the learner (especially the expert learner).

One thing that has become clear from the expert-novice research is that the expert's knowledge base is organized around a more central set of

understandings than the novice's (Chi, Feltovich, & Glaser, 1981). One way to promote accessibility, then, might be to provide students with the concepts and principles most likely to promote expert competence in the domain in question. This requires a good deal of thoughtful analysis on the part of educators. In mathematics, the work of Resnick and Omanson (1987) provides a good example.

Conceptual analysis in mathematics. Through careful analysis and interviews with children, Resnick and Omanson identified a set of principles which provide the basic building blocks for a mathematical understanding of subtraction procedures, at least as taught in American schools. A principled understanding of subtraction is said to involve key ideas like the notion of additive composition (the principle that all quantities are compositions of other quantities), and the principle of partition, which allows one to recompose problems into sets of more easily manipulated subproblems and then cumulate the partial results (e.g., 65-23 converted to a more soluble [60-20]-[5-3]).

Conceptual analysis of the mathematics involved in subtraction--or in Lampert's (1986) research, the mathematics involved in multidigit multiplication--is important because it allows the educator to focus on ideas that apply across an array of phenomena. Principles such as additive composition provide the conceptual basis for various procedures (e.g., addition, subtraction, multiplication); without this linkage, these procedural algorithms are subject to "bugs" of various sorts (Brown & Burton, 1978)--systematic routines such as "borrow-across-zero" (i.e., 606-449) that yield wrong answers. As Gelman (1986) states, "A focus on different algorithmic instantiations of a set of principles helps teach children that procedures that seem very different on the surface can share the same mathematical underpinnings and, hence, root meanings" (p. 350). Understanding of mathematical key ideas contributes to the

development of a coherent cognitive structure and thus enhances the accessibility of the knowledge acquired by students. Connectedness as it contributes to the organization of knowledge will be examined next.

Connectedness. Flavell (1971) has provided perhaps the best definition of cognitive structure:

> The really central and essential meaning of "cognitive structure" ought to be a set of cognitive items that are somehow interrelated to constitute an organized whole or totality; to apply the term "structure" correctly, it appears that there must be, at minimum, an ensemble of two or more elements together with one or more relationships interlinking these elements. (p. 443)

The relationships referred to by Flavell provide the glue that holds the cognitive structure together. Although there are a number of competing ideas about the exact form these links or connections take, with some researchers preferring production systems of the "if . . . then" variety and others leaning toward hierarchical tree models or nomological nets, according to Clancey (in press) the most straightforward model--an association model--may provide the best representation. In such a model, concepts (i.e., key ideas or understandings) are represented as nodes within a system that are interconnected via associative links. Accessibility is a function of the strength of these associative links or relations.

The importance of linkage or connectedness is stressed by a number of researchers. Some, in fact, equate it with conceptual level understanding. Conceptual knowledge is knowledge rich in relationships; as Hiebert and Lefevre (1986) point out, this aspect of structure can be as prominent as the pieces of information being linked. Seeing relationships between units of knowledge is the sine qua non of conceptual understanding. Something understood in this way cannot be an isolated piece of information. Nickerson (1985), however, cautions against treating understanding as if it were a binary concept (i.e.,

having or not having conceptual level understanding). He argues that understanding is a matter of degree. A thorough understanding of something requires knowledge of everything to which it relates. For this reason, understanding can never be complete.

Putting these issues aside, the important point is that organizational structure is provided by the connections or links between elements of the knowledge base. It is the adequacy of this structure that determines the accessibility or availability of information at a later time (de Jong & Ferguson-Hessler, 1986). Good teaching, then, fosters what Skemp (1978) terms "relational understanding." He points out that relational understanding may be harder to acquire, but it is easier to remember. This is because knowing how separate rules (i.e., for computing the area of a triangle and of a rectangle) are interrelated enables one to remember them as parts of a whole, which is easier. There may be more to learn--the separate rules as well as the connections--but the learning is more lasting or accessible. Teachers can help students make connections of the sort Skemp describes.

Three examples of strategies that can foster connectedness follow: The first, that of developing correspondences between various ways of representing concepts and procedures, has been widely employed in both mathematics and science (Janvier, 1987). Kaput (1987) goes so far as to say that "the idea of representation is continuous with mathematics itself" (p. 25). Concrete materials of various sorts are thought to play an important intermediate role in building connections between objects and events in the real world and their symbolic representations (Hiebert, 1984). In science, the role of analogies, metaphors, and physical models have long been recognized as powerful aids in promoting understanding (Gentner, 1981). According to Gould (1980), the ability to

construct fruitful analogies between fields is a key factor when accounting for genius in science.

The second strategy, discussed in the "key ideas" section, involves teaching in a way that makes explicit how important elements of the knowledge base (e.g., concepts and procedures in mathematics) relate to one another. Building bridges in this way clearly enhances understanding (Nickerson, 1985). As argued above, the breadth and depth of a concept's connectedness--that is, how many other ideas it is connected to--is a good measure not only of its meaningfulness but also of its potential contribution to the coherence of a cognitive structure.

The third strategy, which has been the subject of a great deal of research in science education, involves the conscious effort to get in touch with students' naive or informal knowledge. This strategy represents an attempt to connect the understandings teachers are trying to promote with the often strongly held beliefs students bring to the learning task.

Making representational links. Concrete representations can crystallize or give form to concepts and procedures (Mason, 1987). Swing, Stoiber, and Peterson (1988), for example, worked with fourth-grade teachers to enable them to instruct students in the use of certain problem-solving strategies in mathematics, including the pictorial representation of problems. This intervention turned out to be particularly effective for low-ability students, apparently because they do not spontaneously engage in processes like this during problem solving. Other researchers have also found that training youngsters to use pictorial representations to solve mathematics problems is an effective strategy (Charles & Lester, 1984; DeCorte & Verschaffel, 1981).

A certain amount of care must be exercised in this approach, however, as Swing and Peterson (1988), and Lesh, Behr, and Post (1987) point out. For

example, although research suggests that constructing concrete representations for story problems can increase their meaningfulness, some word problems become more difficult when additional information in the form of concrete material is provided (Lesh, Landau, & Hamilton, 1983). Linn and Songer (1988) have identified another problem, in this case associated with attempts to provide students with multiple representations of the same science phenomenon; they find that students often fail to integrate separate representations, preferring instead to focus on the one that is easiest to learn. According to Janvier (1987) such problems occur because we have overlooked the "translation process," the psychological process involved in going from one mode of representation to another.

Schoenfeld (1986) discusses what can go wrong in mathematics instruction when one is too facile in assuming that there is a direct mapping between reference domains and symbol systems. Like beauty, Schoenfeld cautions, the isomorphisms may be only skin deep. To illustrate this notion, he compares the manipulative procedure for subtracting one set of Dienes blocks from another with the base 10 symbol system procedure for subtraction. In the base 10 system, the procedure for subtraction is column independent. The most important issue is whether the digit on the top line is larger than the digit below it. Assuming that the top and bottom digits correspond, one performs the same operations on digits in the second and third columns as one does if the digits are in the first and second columns: Compare, for example, these two problems: 8759-4384 versus 875-438.

The situation is very different with Dienes blocks. In the second problem, children convert one of 7 "tens"--long, rectangular shaped blocks that are the size of 10 "ones" lined up--to 10 "ones." In the first problem, however, one of 7 "hundreds" or "flats" is converted to 10 "tens." Physically, these trades are not equivalent. This may account for difficulties Resnick and Omanson

(1987) encountered in getting children to translate their concrete understanding of subtraction into error-free symbolic manipulations. This novel study deserves further comment.

Resnick and Omanson (1987) painstakingly instructed students in the use of Dienes blocks to see if they would apply principles of arithmetic mastered in a nonwritten symbol system to the symbols of written arithmetic. Despite mapping instruction, which involved a detailed step-by-step alternation between concrete and symbolic routines, there were still persistent bugs in students' performance of the base 10 subtraction algorithm. On the basis of these results, Resnick and Omanson reject the notion that there is a direct transfer of understanding from blocks to written arithmetic. Instead, a careful analysis of interview protocols suggests an alternative hypothesis: Those benefiting from the instruction were somehow able to abstract the core concept--the principle of quantity--which makes mapping possible.

According to Resnick and Omanson (1987), "It is the quantities represented by blocks and written numerals together with parallel exchanges among quantities that permits the mapping" (p. 90). Mapping instruction created a situation that allowed at least some of the children to discern what the types of manipulation had in common. Interestingly enough, verbalization (that is, the extent to which students verbalized about quantities during instruction) was the one variable most related to what students were able to learn from mapping. A more reflective attitude on the part of students toward concrete and written manipulation may lead them to search for principles that connect the two types of transaction.

According to Mason (1987), the difficulty that teachers face in using concrete representations is part of a larger problem of getting students to see

"the general in the particular." Students have a tendency to take representations literally. They may concentrate on learning the representations rather than seeking to understand what it is that the representations represent:

> [Students] are probably often blissfully unaware that what they are learning is only partly presented by the diagrams and symbols; that they are being offered windows through which to glimpse or experience something that they too can try to express in a similar mode. (Mason 1987, p. 213)

Thus, it is important that students keep in mind that the representation is not reality; it is simply another more or less effective way of construing that reality. In making representational links, it is important that teachers develop this sort of awareness in students.

Metaphors and analogies are types of representation that warrant separate mention. As Vosniadou and Brewer (1987) indicate, analogy is a powerful mechanism for getting children and adults to transfer information from a known domain to a new one. Comparing electricity to traffic or water flow is an example. Although electricity and water are dissimilar, they have in common the fact that both move in a fluid sort of way. Analogies differ from metaphors in that the comparisons analogies make are more explicit (Petrie, 1979).

The use of metaphor in teaching has been the subject of a good deal of research (Ortony, Reynolds, & Archer, 1977). According to Haynes (1975), good metaphors are "interactive" in a way that parallels good concrete representations (see above); that is, they result in a meaning that is new, transcending the meaning of the subjects being compared. The metaphor creates the similarity, it does not simply capture what is already present. Mayer's research (1975a, 1975b) shows how metaphors facilitate connectivity. He presented information about computers to two groups of naive students. One treatment involved the presentation of an extended metaphor, with input likened to a ticket window, output to a chalkboard, and so forth. The other was a more traditional

presentation, consisting of a flow chart representation of computer functions. Consistent with the hypothesis, the metaphor treatment facilitated external connections, resulting in the production of more examples, while the flow chart treatment facilitated internal connections, with subjects better able to produce flow charts. This supports Petrie's (1976) claim that metaphor is a important pedagogical tool for bridging disciplinary gaps that result from differ ences in the way people perceive phenomena.

Connecting Elements of the Knowledge Base

It has long been recognized that good teachers present knowledge in such a way that students are able to integrate it with and differentiate it from what they already know. In presenting a new concept, for instance, good teachers deliberately compare and contrast it with previous concepts (Steinberg, Haymore, & Marks, 1985). This is one way of fostering connectedness and thus of contributing to the accessibility of the knowledge being acquired. In mathematics, a great deal of attention has been focused on the issue of connectedness--particularly as it pertains to two important elements of the knowledge base: concepts (i.e., key ideas) and procedures (i.e., computational algorithms). There are numerous examples of what can go wrong when students fail to connect these two types of information. Schoenfeld (in press) cites several that stem from work done by Reusser. In his dissertation research, Reusser found that three quarters of the 97 second graders he interviewed "solved" the following problem by simply adding the numbers 26 and 10: There are 26 sheep and 10 goats on a ship. How old is the captain?

According to Schoenfeld (1982), this mindless approach to problem solving is actively promoted through use of the so-called "key-word" method, which teaches students to choose arithmetic operations in word problems by looking

for syntactic cues such as the word "left" (an indication that subtraction is in order). He cites one study where this key word was conspicuously displayed even though the operation it signaled was inappropriate. The situation was so extreme, Schoenfeld reports, that many students decided to subtract when the problem began with "Mr. Left . . ."

In mathematics, and other subject matter domains, it is possible to learn procedures by rote. However, it is much less likely that such procedures will be retrieved and used appropriately. The assumption is that procedures that are conceptually understood are much more likely to be accessed when needed. Conceptual knowledge frees up the procedure from the surface context in which it was learned and facilitates its transfer to other structurally similar problems (Hiebert & Lefevre, 1986). It also simplifies the process: Instead of learning two different subtraction procedures for borrowing across zeros and nonzeros, for example, one masters a single procedure known as regrouping. Procedural knowledge is extremely limited unless it is connected to a conceptual knowledge base.

Hiebert and Lefevre (1986) identify two types of knowledge relationships in mathematics. One, which they consider primary, might be termed a lateral connection. The relationship does not transcend the level at which the knowledge is currently represented. The example they provide is of a student who connects knowledge about the position values to the right of the decimal point with an understanding that one should line up decimal points prior to adding or subtracting decimal numbers. Putting these two pieces of information together when adding decimals could lead to the realization that one is adding tenths to tenths, hundreths to hundreths, and so on.

The second type of connection, which they term reflective, is at a higher, more abstract level than the pieces of knowledge being connected. This type of

relationship is less tied to a specific context. According to Hiebert and Lefevre (1986), it takes in more of the mathematical "terrain." Building on the previous example, it might involve connecting knowledge about the addition of decimals with that relating to the addition of common fractions. Looking for a common denominator and lining up decimal points are both seen as a special case of the notion that only "like things" can be added together. (The abstracted sense of quantity that Resnick and Omanson, 1987, argue for is another example of a reflective connection.)

Fostering this type of connectedness is obviously important in education. Networking and concept mapping represent two instructional techniques that attempt to make more explicit the connections between concepts. In networking, narrative prose is transformed into node-link maps or networks (Dansereau, 1985). It involves breaking passages of text material down into parts and then identifying the nature of the relationship between those parts. Concept maps are also largely diagrammatic or spatial representations of the relations between concepts.

According to Novak and Gowin (1984), they are powerful pedagogical tools because they allow students to visualize concepts and the hierarchical relationships between them. The authors claim that concept mapping is a good device for "negotiating meaning" with students (see below). Concept maps allow people to make explicit their views about how different concepts are related and why certain links are more or less valid. They thus may serve as an impetus for subsequent learning.

Novak (1981) presents data gathered on seventh and eighth graders that indicate that mapping can be taught and that it facilitates problem solving and the comprehension of text material. Concept maps are also considered effective tools for revealing student "misconceptions." According to Novak and Gowin

(1984), they help identify concepts which may be missing or incorrectly linked in the student's conceptual framework. In this sense, they may contribute to another approach which promotes connectedness--that of building on or playing off the informal knowledge students bring to the learning task. Apparently, that knowledge is quite extensive.

Informal knowledge. It is now recognized that children bring a great deal of informal or naive knowledge to any learning situation. This knowledge can facilitate or interfere with acquisition of the more formal knowledge about subjects taught in school. Evidence for intuitive understanding in mathematics comes from a growing body of research demonstrating that children develop an understanding of mathematics on their own (Resnick, 1986). One example of invention come from research on children's addition and subtraction strategies. This work, which relies on observation as well as interview and think-aloud protocols, strongly suggests that children begin formal instruction in mathematics already understanding at least one key mathematical concept: the additive composition of number (Resnick, 1986). The notion that all numbers are compositions of other numbers is basic to the study of elementary arithmetic.

The invention of mental counting procedures for addition and subtraction constitutes strong circumstantial evidence for the presence of at least an implicit understanding of this idea (Resnick, 1986). Figuring out the answers to subtraction problems by counting down from larger numbers or counting up from smaller numbers, whichever is most efficient, is a good example of an invented procedure that depends on the ability to decompose a larger number into parts. If, in fact, children do possess intuitions of this sort, there may be advantages in having them serve as a basis for much of what is taught in elementary school mathematics. Unfortunately, there is little evidence that

teachers build on students' informal knowledge: "The focus in school mathematics on formal symbol manipulation discourages children from bringing their developed intuitions to bear on school learning tasks" (Resnick, 1986, p. 162). It is important, however, that better ways be devised to foster connectedness between the formal and informal knowledge structures developed by children.

Science provides the most vivid examples of the role of informal knowledge in the learning process. In this domain, however, the role is <u>not</u> always facilitive, in fact, quite the opposite. One goal of science instruction is to help children develop new frameworks for understanding phenomena, and these frameworks frequently conflict with those the child has developed spontaneously. Informal knowledge which interferes with subsequent learning is described by a variety of terms, including "intuitive conceptions," "misconceptions," "naive theories," "alternate frameworks." That these notions exist and are extremely resistant to change has been documented in scores of studies covering all scientific disciplines (Anderson & Smith, 1987). In physics, for example, novices are said to hold theories that resemble more those of Aristole than Newton (White, 1983); furthermore, these views are relatively unaffected by instruction on Newtonian mechanics (Clement, 1982).

Getting students to alter preconceptions is not easy. Students must first be dissatisfied with them in some way, then must find the alternatives both intelligible and useful in extending understanding to new situations (Posner, Strike, Hewson, & Gertzog, 1982). According to Anderson and Smith (1987), the direct confrontation of naive conceptions is a characteristic of most successful attempts to promote conceptual change. However, textbooks and teachers frequently fail to "connect" naive and scientific views in this way. Roth and Anderson (in press) have demonstrated this by following students through a unit

on photosynthesis. Despite six to eight weeks of instruction on this topic, only 7% of the 229 fifth graders in one study were able at the end of the unit to explain that plants get their food by making it themselves. According to Roth and Anderson, it is unrealistic to think that students will change their beliefs about plants by simply adding the photosynthesis notion to their rich prior knowledge.

For meaningful learning to occur, the new knowledge has to connect or interact with the prior knowledge. Students often fail to make this connection on their own. In addition as Roth and Anderson (in press) explain, the process is more complex than appears: Students must first recognize that the new information is related to what they already know; they then have to link this information to two types of prior knowledge--that which is consistent with the scientific notions and that which is incompatible with those notions. It is the latter connection which leads to the realization that their own ideas are not complete or satisfying explanations and that the scientific view is a more convincing and powerful alternative.

It is obvious from research cited above that learners are not blank slates. They possess a great deal of informal or naive knowledge that influences learning in virtually all academic domains. It is important that teachers get in touch with this informal knowledge. Connections with knowledge that is consistent with the understanding teachers are trying to foster can add to the coherence and stability of the overall structure. If the informal knowledge is inconsistent with the new information, it is important that it be altered or changed. Either way, the need to provide links between formal and informal knowledge should not be ignored.

Summary. Two factors that help determine the extent to which students can access knowledge when needed have been identified. In this section, the focus

has been on the first factor, which is organizational in nature: The better organized or structured the knowledge, the more accessible it is. At the knowledge base level, organization is largely a function of connectedness. There appear to be a number of ways that teachers can foster connectedness. First, they can be extremely selective in terms of the ideas or concepts they present, making sure that the ideas they do emphasize have potential for developing knowledge that is rich in relationships. Second, they can promote the use of various representational formats on the part of students; in the process of translating from one symbol system to another, students frequently discover the underlying concepts that connect different forms of representation. Finally, the research discussed in this section suggests that teachers should make a conscious effort to get in touch with students' informal knowledge. The type of "connection" they develop will depend upon whether or not the acquisition of new knowledge is helped or hindered by the informal knowledge students bring to the learning situation.

Awareness

Access to knowledge is thought to be fostered when students are made more aware of what they know and do not know about a subject. The role that awareness plays in understanding has been a subject of speculation in psychology and epistemology for a long time. It is at the heart of important distinctions between different forms of knowledge. Michael Polanyi (1958, 1966), for example, contrasts tacit and explicit knowledge; tacit knowledge is knowledge of which we are normally not aware. Bialystok and Ryan (1985) use the terms analyzed and unanalyzed knowledge to express a similar notion. Unanalyzed knowledge is understood superficially, as a general pattern, and tends to be used in a routine, nonreflective way. Analyzed knowledge is used creatively; it is an

object of thought. By attending to the structural properties of analyzed knowledge, one can consciously transform it.

This ability to consciously attend to one's knowledge state is said to be a hallmark of human intelligence (Gardner, 1978). Not only does reflective awareness increase with development (Flavell, 1985), it also varies as a function of the amount of understanding one has achieved in a domain: As one researcher puts it,

> It is interesting that ignorance--more accurately, awareness of ignorance--at one level can be evidence of understanding at another level. In the absence of some degree of the general understanding that prompts more specific questions, one does not know enough to be aware of one's ignorance. (Nickerson, 1985, p. 221)

The role of verbalization. Apparently, the development of reflective awareness in children does not allow for shortcuts. Verbalization appears to be the best means for achieving this purpose. Thus, there is considerable support for the notion that discourse or dialogue plays a vital role in promoting student understanding and reflective awareness in a number of academic domains, such as science (Anderson & Palincsar, 1987), mathematics (Lampert, 1986; Whimbey & Lochhead, 1980), history and literature (Barnes, 1975). This research has not had much influence on teaching to date. Conversation in the classroom is generally considered a nuisance (Cazden, 1986). Researchers have documented the fact that teacher talk is extremely prominent during instruction--which no doubt reflects the prevailing view of teaching as information transmission (Lochhead, 1985).

According to Piaget (cited in Lochhead, 1985), the act of verbalizing is directly associated with bringing the subconscious to consciousness. In the process of relaying thoughts to others, we also relay them to ourselves. It is the process of formulating thoughts into communicable representations that is most important in developing an awareness of what one knows. Through

verbalization, our thoughts become an object for reflection. As such, they can be "operated on" in a Piagetian sense. As Lochhead (1985) puts it, one can systematically analyze and modify the components.

In finding words to express ideas to others, we wind up reshaping them for ourselves (Barnes, 1976). Piaget did not equate speech with thought; the ability to think was said to proceed independently of knowledge about language (Sinclair-de-Zwart, 1969). However, Piaget did emphasize that much of our knowledge is tacit. Speech provides a means of bringing this knowledge to light and of controlling it. Barnes (1976) summarizes the Piagetian position thusly, "Talk and writing provide means by which children are able to reflect upon the bases upon which they are interpreting reality, and thereby change them" (p. 31).

This notion--that knowledge changes as we recode it--has been around a long time (Bruner, 1966). Nevertheless, it has not much affected classroom practice:

> There are big gaps between "seeing" something, being able to "say" something, and being able to "record" that saying on paper in pictures, diagrams, words, and symbols. The importance of struggling to try to say what we See, and then to Record what we Say has been noted so often that it is a cliche to say that only when you try to teach something do you really come to understand it. What is curious is that the cliche has not been incorporated into teaching practice. Very rarely are students actually given enough time to engage in the struggles for themselves. Instead we rush them from initial exposure to written records. (Mason, 1987, p. 210)

Writing about content. Students gain awareness when they are encouraged to articulate their own thoughts. It is through this process that students' oversimplifications and naive conceptions are revealed. Consistent with this notion, there is a growing body of literature suggestive of how writing can promote understanding of subject matter content (Britton, Burgess, Martin, McLeod, & Rosen, 1975; Tchudi & Tchudi, 1983). Ammon and Ammon (1987), for example,

had students write about science experiments to which they had just been exposed.

Apparently, the benefits students realize by writing about content vary as a function of the level of understanding they are able to achieve prior to the writing activity. Thus, for those students who arrived at a new level of content understanding during one of the experiments, writing served as a way of consolidating the understanding. In fact, the most effective writing was done by these students; Ammon and Ammon (1987) speculate that this may due to the fact that they were working through a line of argumentation that they had recently gone through for the first time. It was still fresh in their memory. In addition to the consolidation function, writing also played a bootstrapping role for some students. By making evident certain inconsistencies in their thinking, it served as an impetus for resolving the inconsistencies and moving toward a higher level of understanding.

Classroom dialogue. Discourse about content not only helps the communicator, it also helps those with whom one is communicating. Since Socrates, we have acknowledged the educational significance of dialogue and discussion. There is good theoretical justification for this. Although Piaget did not devote much attention to the role of social interaction in his theory, he did recognize its importance in fostering knowledge growth. According to Sinclair (1987), he felt that objective knowledge was obtained only when it had been discussed and checked with others.

James Moffett (1968) associates dialogue with dialectic: "The internal conversation we call thinking recapitulates previous utterances as amended and expatiated on" (p. 233). Confrontation with alternative views exposes the limitations in one's own point of view. This serves as an incentive to modify one's thinking. As Brown and Campione (1986) explain, "Understanding is more

likely to occur when a student is required to explain, elaborate, or defend his or her position to others; the burden of explanation is often the push needed to make him or her evaluate, integrate, and elaborate knowledge in new ways" (p. 1066).

The educational advantages of this type of interaction--as exemplified by cooperative learning groups--are well documented. Yager, Johnson, and Johnson (1985), for example, compared three variables that might mediate the relationship between cooperation and achievement. By contrasting cooperative and individualistic learning situations, and manipulating the extent to which oral discussion was structured within cooperative groups, the researchers were able to demonstrate that the quality of verbal interaction within the groups made a significant contribution to the efficacy of cooperative learning. The careful structuring of oral interaction within the groups--ensuring that all members were involved both in explaining material to be learned and also in monitoring the other students' summaries, giving corrective feedback when necessary--had a positive effect on retention of the material.

Conditionalizing knowledge. Strategies other than the discourse strategies talked about above are also effective in promoting knowledge awareness in students. Most of these strategies involve conditionalizing knowledge in various ways; that is, providing information to students about the contexts in which the knowledge, either conceptual or procedural, might be used (Bransford et al., 1986). Duffy et al. (1986) have demonstrated the importance of providing information of this sort in teaching reading skills to fifth graders. In their study teachers were trained to be very explicit regarding the context in which specific skills, such as breaking down a compound word, could be used. The following is an example from a lesson excerpt: "This skill is one that you use when you come to a word you don't know and you have to figure out what the word

means. You can use it any time you run into a word you don't know" (p. 242). It was hypothesized that teacher explicitness would increase student awareness of what was taught, an hypothesis strongly supported by the results.

Providing contextual information is important if one wishes to promote problem solving. A problem can be defined as a situation where one has a good idea about what should be accomplished, but no clear idea about how to go about accomplishing it (Duncker, 1945; Davis, 1973). Newell and Simon (1972) characterized it this way, "A person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it" (p. 12). Problem solving, then, is basically a question of transfer of learning; it is "the application of known concepts to new situations" (Shumway, 1982, p. 132). This view is consistent with the way cognitive researchers have approached problem solving (Lester, 1982). It begs the question, however, about how the transfer process occurs. A key aspect of this process is problem representation--translating the problem statement into some sort of internal mental representation.

According to Simon and Simon (1978), the more precise or "perspicuous" the representation, the better:

> When a physical situation is described in words, a person may construct a perspicuous representation of that situation in memory. By a perspicuous representation, we mean one that represents explicitly the main direct connections, especially causal connections, of the components of the situation. For example, in a statics problem involving a ladder leaning against a wall, the representations might be an associational structure with nodes for the ladder, the wall, the floor, and the points of contact between the ladder and the wall and ladder and the floor. The force of gravity acting on the ladder would be associated with those points. Once this schema had been constructed in memory, it would be a straightforward matter to construct the equations of equilibrium for the situation. (p. 337)

Perspicuous representations are important in other domains as well. Paige and Simon (1966), for instance, presented students with algebra problems that

corresponded to physically unrealizable situations; in attempting to solve these, students apparently unintentionally transformed them into similar problems which were physically realizable.

Being able to create an adequate representation of the problem is only half the battle, however. One must be able to relate this representation to a previous one which resulted in correct problem solution (Greeno, 1977). It is this relating of one problem situation to another that mediates access to potentially relevant conceptual and procedural knowledge. Teachers can foster the transfer of knowledge necessary for problem solving by pointing out features of the problem situation which, if present in future situations, would suggest further utilization of the same information. This is consistent with Polya's (1973) advice to teachers; he suggested that they have students imagine future situations where they could apply their newly acquired problem-solving procedures. Presumably, this could be done during problem-solving exercises. These exercises should provide a good occasion for developing understanding of "prototypical structures" such as those identified by Riley, Greeno, and Heller (1983) for arithmetic word problems.

Pea (1987) makes a similar point, arguing in favor of an interpretation rather than physical feature characterization of transfer. He maintains that it is the learner's construal of context rather than some physically measurable quality of the environment that is most important in determining whether transfer will occur; common elements are interpreted, not given in nature. By carefully selecting transfer examples, he believes, students can be taught to "read" situations and develop their own classification schemes for problem types. Pea believes that greater effort should be devoted to defining common perceived elements across various types of problems; this is necessary for the

development of techniques that would teach students how to analyze situations in order to promote knowledge transfer.

Broadening the problem-solving purview. It is important to bear in mind that problem-solving situations represent a subset of the almost limitless number of situations in which access to potentially relevant knowledge, strategy, or disposition is at issue. As a number of researchers have pointed out, many domains consist of ill-structured situations that hardly qualify as problems. This is true of the social sciences (Cornbleth, 1985). It is harder in this domain to specify situations where conceptual knowledge might be relevant. What is the context for accessing knowledge about checks and balances, for example? Voss (1987) provides an example of the sort of ill-structured problems one encounters in social studies: Reducing the crime rate within a particular community. The goal is vague; it is unclear what constitutes the desired outcome. Constraints are not built into the problem, nor is it clear what steps, if any, will lead to a solution.

Recognizing that there are significant differences between this type of problem and the well defined problems students encounter in geometry or physics, Voss (1987) nevertheless sees enough similarity and enough advantage in a problem-solving approach to argue for its use in social studies. The focus in such an approach would not be on problem solving per se, but rather on providing a rationale for a particular interpretation of the problem and a justification for various proposed solutions. The advantage to such an approach is that students become much more aware of how the knowledge they are acquiring can be put to use. Adopting a problem-solving mentality, even when it is marginally appropriate, reinforces the notion that the knowledge being acquired is useful for achieving particular goals. Students are not being asked to just store knowledge away; they see how it works in certain situations, which increases

its accessibility. Knowledge relevant to problem solving enjoys an awareness advantage that teachers should exploit if possible.

Summary. In this section, a second set of variables thought to exert an important influence on accessibility were examined. Unlike the first set, which relates to how knowledge is organized, the variables discussed in this section are presumed to increase accessibility to relevant knowledge by making students more aware of their own knowledge state. The argument that was advanced can be summarized as follows: Getting students to write about content, and engage in dialogue to explain and defend their views, enhances access because it forces them to attend consciously to what they know about various subjects. It thus serves as an impetus for students to rework their ideas, leading to changes in the way knowledge is organized or structured. Based upon the theory and research presented in this section, it does appear that organization and awareness factors interact in this way. This type of interaction may occur in the strategy and dispositional categories as well.

Strategies

Included under the strategy rubric is a broad range of routines, extending all the way from various heuristic techniques that allow one to more easily access relevant information during problem solving (e.g., considering a similar problem with fewer variables in mathematics), up to very general control strategies such as planning, monitoring, checking, and revising. Some justification needs to be provided for including heuristic techniques in the same category as executive control skills. As Bereiter and Scardamalia (1985) point out, heuristics are considerably more complex than algorithmic rules, which can perhaps better be considered part of the knowledge base. Algorithms are practical only for an extremely limited range of activities--those that lend themselves to

very precise specification. Such activities, according to Bereiter and Scardamalia, are mostly confined to the realms of logico-mathematical problem solving.

Heuristics or "tricks of the trade" are less wedded to specific activity/goal contexts. Nevertheless, they can be thought of as marking the low end of the executive control continuum because they do take on quite specific characteristics depending upon the particular domain in which they are being applied. For example, in the reading domain, the techniques for more efficiently extracting information from text may be considered a direct analogue to the problem-solving heuristics Schoenfeld (1985) has identified in mathematics. Thus, knowing how to use devices such as headings, introductions, and summaries simplifies the "problem-solving process" in reading by directing students' attention to the most informational aspects of text in a way that is comparable to the techniques students are taught as a way of facilitating the problem-solving process in mathematics.

As indicated in the introduction, executive control strategies such as planning and checking, in contrast, may retain their essential character regardless of the domain of application. Planning, the process of carefully considering activities prior to undertaking a task (e.g., scheduling specific moves and engaging in various forms of vicarious trial and error), appears to have a sameness about it that transcends specific instantiations. In reading, for example, planning may consist of skimming the entire text to get a feel for its overall structure, making judgments about how best to allocate one's time in order to maximize learning, and so forth. In mathematics, planning may involve outlining a solution to a problem at a very general level, deciding to elaborate it in detail as the solution proceeds.

Similarly, checking as a cognitive process may take on only slightly different form depending on the content area in which it is applied. In reading, it presumably consists of trying to state the main points in a segment of text that one has just read, whereas in mathematics it might involve checking the reasonableness of one's answers to mathematical problems (Hiebert & Wearne, 1986). In both cases, the person is testing to see whether they apprehend the "big picture." This being the case, of course, the most efficient approach to teaching executive control strategies would appear to be the one that is most general. Bereiter and Scardamalia (1985) support this notion, indicating that general self-regulatory functions are most needed in those task domains where algorithmic rule systems, if they could be developed, would be too complex to teach. Promoting general functions, by and large, has been the strategy of preference in recent work in cognitive science.

Organization

As indicated, the search for ways to teach executive control strategies has highlighted the importance of the same two factors discussed earlier in connection with the knowledge base. Of the two, organization and awareness, the organizational issue has been the most difficult to finesse, and for good reason. At the crux of this problem is what has been termed the "specific-general controversy": the realization that there is a tradeoff between strategy specificity, power, and teachability on the one hand, and strategy generalizability on the other. Thus, the more specific, narrowly defined the strategy, the more powerful it is in the sense of guaranteeing a result once accessed. Specific strategies are, by definition, very prescriptive. Because such strategies involve the application of fairly simple routines to specific

tasks, they are also relatively easy to teach. An example might be instructing students in the use of a key-word mnemonic for vocabulary acquisition.

The problem with very specific strategies, however, is that each has what Newell (1980) terms a "small penumbra of generality" (p. 185). Specific strategies do not readily transfer to new, potentially relevant situations. In such situations, learners are faced with the almost impossible task of having to sort through hundreds and hundreds of specific routines to find the one that may be most appropriate. An alternative approach is to concentrate on more general, executive control skills. Although weaker in the sense of being less prescriptive, such strategies are more generalizable: "The executive, self-regulatory skills that are weak to some extent evade the transfer problem because they are appropriate in almost any situation; no subtle evaluation of task demands is necessary" (Brown, 1985a, p. 331). The problem with this approach, of course, is that it is very hard to operationalize such vague or abstract processes.

The search for solutions to organizational problems similar to the one mentioned above has occupied a great deal of time on the part of cognitive scientists. This effort is motivated by two important beliefs. One is that the expert has available a more general, flexible set of strategies than the novice, whose skills are much more "welded" to particular contexts (Brown, 1982). Therefore, it seems worthwhile to promote executive control strategies in children. The other, a corollary to the first, is that development represents to some extent a novice-to-expert process. In other words, development is the process whereby individuals proceed from a specific, context-dependent state to a relatively context-independent state where they are able to use cognitive resources flexibly, in a variety of situations. Knowledge is never context-free, but, as Brown et al. (1983) point out, the degree of contextual "binding"

varies a great deal. They argue that the range of applicability of any particular process is the best indicator of either expertise or cognitive maturity on the part of the learner. Thus, the desire to promote executive control skills in learners is buttressed by both expert and developmentally based arguments.

Cognitive apprenticeship. Progress in promoting executive control strategies has been partly the result of trial and error, albeit guided by conceptual analyses of the processes involved in particular subject matter domains. Work of this sort has also been strongly influenced by the theorizing of Vygotsky and by recent work on teaching and learning in everyday contexts (cf., Rogoff & Lave, 1984). The widely acclaimed reciprocal teaching program developed by Palincsar and Brown (1984) demonstrates the confluence of these theoretical and empirical factors. The interactive mode of training employed in this work mimics the real life teaching of mothers (Wertsch, 1979) or master craftsmen (Childs & Greenfield, 1980), which supposedly epitomizes Vygotskyian principles of mediated learning. The actual activities selected to foster comprehension-monitoring in the Palincsar and Brown study were distilled from a careful review of the reading education literature; their procedure was similar to a reciprocal questioning intervention used by Manzo (1968) some years earlier. Following extensive pilot work, teachers were trained in the technique for use with naturally occurring groups in the classroom.

Their training procedure involves teachers working with students in dyads or small groups, with each member taking turns in leading a dialogue concerning a segment of text. The dialogue leader paraphrases the main ideas, clarifies any ambiguities, raises possible questions about that segment, and hypothesizes about the future content of passage segments. Initially, all these activities are carefully modeled by the teacher, with a gradual shifting on the part of

the students from a relatively passive or imitative role in the process to eventually being able to assume full responsibility for the comprehension-monitoring activity. The increases in reading comprehension with this approach have been dramatic. Palincsar and Brown (1984) have also been able to demonstrate impressive transfer effects across subject matter domains (i.e., comprehension of social studies and science text materials), with related but different types of measures, and over a prolonged period of time.

Collins, Brown, and Newman (in press) compare the approach of Palincsar and Brown with two other outstanding attempts to teach higher order, executive control strategies: Schoenfeld's (1985) method for teaching mathematical problem solving and Scardamalia and Bereiter's (1985) approach to the teaching of writing. All three programs emphasize the development of self-monitoring and self-correction skills in learners--and they all employ what Collins et al term a "cognitive apprenticeship" model of teaching. This approach is designed to bring tacit processes into the open, "where students can observe, enact, and practice them with help from the teacher and from other students." To this end, it is important that the learning be situated: that is, that students learn strategies in the context of their application to realistic problems or concerns. One of the strengths of the reciprocal teaching approach is that comprehension monitoring strategies are embedded in an instructional context in which participants share the goal of deriving meaning from text (Brown, 1985b). Similarly, Schoenfeld uses realistic mathematics problems to teach the problem solving process in that domain.

The necessity to situate or contextualize executive control processes in this way means that very general, content independent strategies are not very good bets for future research. If there is a continuum defined by very specific skills on one end and very general skills on the other, perhaps we should

not venture much beyond the midpoint in our search for learning strategies that transfer or generalize across situations. Thus, Brown et al. (1983) are probably correct when they characterize the executive control strategies they are teaching as being "intermediate" in generality. Given the multiple criteria that should apply in evaluating strategy interventions (i.e., feasibility, generalizability, and "power") intermediate level processes may represent the optimum choice.

The search for solutions to organizational problems similar to the one mentioned above has occupied a great deal of time on the part of cognitive scientists. This effort is motivated by two important beliefs. One is that the expert has available a more general, flexible set of strategies than the novice, whose skills are much more "welded" to particular contexts (Brown, 1982). Therefore, it seems worthwhile to promote executive control strategies in children.

Summary. The organizational issue addressed in this section concerns the type of strategy that should be targeted for instruction. It was argued that there is a tradeoff between general and specific strategies. Specific strategies involve the application of fairly simple routines and are easily taught; however, they do not readily transfer to new situations. General strategies, on the other hand, are much more flexible, but they are difficult to teach. Attempts to operationalize such processes result in very vague sounding statements that are not particularly helpful in terms of knowing where to begin instructionally. Recent work by Brown, Schoenfeld, and others, appears to support a "middle range" solution to this problem. Based on Vygotskyian principles of mediated learning, these researchers have developed techniques that allow one to teach executive control skills grounded in content specific problems and applications. An advantage of this sort of situated learning is that

it encourages students to master strategies in a holistic way, where both the purpose and the effect of the activity is relatively transparent.

Awareness

While some of the organizational issues surrounding strategy training still need to be resolved, there is near unanimous agreement regarding the importance of reflective awareness as it relates to executive control skill. Lawson (1984), in fact, makes a good case for restricting use of the popular term "metacognition" to exactly this aspect of thinking. In much of the research, metacognition refers to both awareness and control aspects of cognition. According to Lawson, the conflation of these two dimensions in several studies has led to conflicting patterns of results. He argues that knowledge of cognition can and should be separated logically and empirically from control of cognition. This section focuses on the awareness dimension of cognition and, in this paper, the term metacognition refers only to this dimension. Awareness does have implications for control, however. According to the view developed here, it contributes to the student's ability to access learning strategies when needed.

Conscious knowledge of intellectual functions, being able to "mention as well as use" (see Brown, 1982), has been considered the hallmark of mature cognition. Surprisingly, the awareness dimension was ignored in the early strategy training studies. Brown et al. (1983) distinguish between these studies, termed "blind training studies," and the later studies in which a conscious effort was made to inform subjects about the benefits of the strategies they were induced to use. Subjects in the informed training studies were much more likely to transfer strategies to new situations. Butterfield and Belmont (1979) go so far as to suggest that any of the blind training studies that show

successful strategy transfer can attribute this result to the inadvertent training of metacognition (i.e., awareness).

Research by Kurtz and Borkowski (1984) illustrates the advantages of informed strategy training procedures. They taught summarization skills to groups of middle school students. Based on earlier work by Kintsch and van Dijk (1978), students were instructed to use superordinates, identify main ideas, and invent topic sentences. Students in the strategy group received explicit instruction on each of the component strategies of summarization. Students in the executive group received strategy instruction along with instruction on the benefits of self-monitoring while reading and the importance of carefully choosing and evaluating strategies to enhance comprehension. Students in the control group wrote summaries on the experimental material. Those in the two treatment groups performed better than the controls; more importantly, those in the executive group, who received both control and awareness training, outperformed those in the strategy alone group.

The ability to access relevant strategies in new learning situations thus relates to the amount of reflective awareness possessed by the learner. It is worth reiterating, however, that the role of reflective awareness or metacognition is not limited to executive control strategies. Information regarding the conditions and constraints which govern any type of knowledge use (conditionalized knowledge) is of central importance in all three types of cognition: knowledge base, strategic, and dispositional. The most important kind of knowledge in this regard may be interactive in nature. Certain strategies, for example, may be useful only in the context of certain kinds of material, or a certain amount of prior knowledge. The nature of the material to be learned, the amount of relevant knowledge at one's disposal, the way the outcome of the learning process is defined--all constitute important factors that

students need to be aware of to understand how strategies can be differentially effective.

Strategic level-knowlege base interaction. Research supports the contention that the type of strategy used and the nature of the material to be learned interact in important ways. For example, representational strategies involving imagery apparently work best with concrete as opposed to abstract text material (Pressley et al., in press). Similarly, the effectiveness of free recall strategies is influenced by the type of materials being processed: If categorical relations are not inherent in a word list, than a strategy based on categorization cannot be effective (Ornstein & Naus, 1978). At a more general level, textbooks differ in terms of their cohesiveness and structure (Armbruster, 1984). "Inconsiderate" text, which lacks a clear overall structure, makes it much more difficult for the reader to extract main ideas; it thus demands greater executive control skill on the part of the learner.

Knowledge base factors can also more directly influence the use of strategies. For example, the amount of relevant knowledge at one's disposal is a key factor in determining the extent to which one ought to rely on general versus more context specific strategies. As Scardamalia and Bereiter (1984) suggest, general strategies play a more important role when conceptual knowledge is meager. Also, they may be relatively more important during early phases of the learning process, when it is less clear what is required.

Another example of the interaction between knowledge base and strategy use can be found in Hasselhorn and Korkel's (1986) study. They compared children who were soccer experts with those who were novices in this regard. Baseline data were gathered relating to subjects' ability to detect inconsistencies in a short story on soccer; not surprisingly, experts were twice as adept at this as

novices. Half the subjects in each group were then assigned to a treatment and control group.

In the treatment group, subjects were taught a reading strategy that depended on prior knowledge for its effectiveness. Specifically, they were taught to use a comprehension-fostering strategy that involved the activation of previous knowledge about soccer as an aid in evaluating the current text. Control group subjects were taught some general comprehension-monitoring strategies (e.g., self-questioning). Comprehension fostering resulted in better performance than comprehension monitoring for the experts, but the opposite result obtained for novices. The novices instructed in comprehension monitoring outperformed those taught to make use of what they already knew about the subject in question. Thus, although both these strategies are general in nature, one is more dependent on the knowledge base than the other.

Strategic level-outcome interaction. One additional factor influencing strategy use must be mentioned, although to some extent it is discussed in the last section of the paper, where the role of dispositional factors is treated. This is the criterial task factor. Independent of what students may know about a subject, the criteria they use to define the end product of the learning process has a profound impact on the kinds of strategies they employ. The focus thus far has been on conceptual level (or richly connected) understanding. This is the most durable form of knowledge that students can acquire. Students should be equipped strategically and dispositionally to seek this type of knowledge whenever possible. However, there may be times when it is reasonable to settle for less. On those occasions, strategies compatible with more modest learning goals are called for.

If, for example, the desired outcome is correct recall of verbatim information, then simpler mnemonic strategies are better suited to the task

than more complex strategies of the Palincsar-Brown (1984) variety. Barnett, Divesta, and Rogozinski (1981) reinforce this view. They argue that comprehension-fostering strategies may be counterproductive when the learning task demands nothing more than the reproduction of factual knowledge. There may be times, then, when higher order strategies are inappropriate. It is hoped that these instances will represent subgoals in the learning process, where discrete factual knowledge is committed to memory in pursuit of more significant outcomes. (An example in music might be use of a first-letter mnemonic aid to memorize notes on the treble staff; for example, Every Good Boy Does Fine for the notes E, G, B, D, F). It is also hoped that a student will possess conditional knowledge of this sort and thus be equipped to make decisions regarding strategy use in an intelligent manner.

Summary. In this section, it was argued that the ability to access potentially relevant strategies is influenced by awareness factors in a way that is similar to what occurs in the knowledge base category. The instructional implication one can draw from this discussion about strategies is comparable as well. Thus, the more explicit teachers can be about the factors that affect strategy use, the better. These factors include the amount of prior knowledge possessed by the learner, the nature of the material to be learned, and the kind of outcome the learner is trying to achieve. As Bransford, Stein, Shelton, and Owings (1986) point out, conditionalized knowledge of this sort may serve as a "trigger" for strategy use. Awareness defined in this way is thought to be highly relevant to one's ability to access strategies when needed.

Dispositions

The relationship between strategy and disposition is the key organizational issue addressed in this last section of the paper: To what extent must certain

dispositions be "grounded" in certain outcome-related strategies? It may be, as Biggs (1984) suggests, that some motive-strategy combinations are more congruent that others; a mastery disposition, for example, appears more congruent with Palincsar and Brown's (1984) comprehension-monitoring strategy than it does with strategies relevant to test taking or memorization. Biggs argues that congruence between motives and strategies is an important criterion in learning effectiveness. This issue is examined below, as is the awareness issue: To what extent can learners be made consciously aware of the motivational dispositions or beliefs that influence their behavior? What is the relationship between dispositional awareness and one's ability to perform the behavior called for by the disposition.

An important new theory that directly addresses this issue of the relationship between organization and awareness factors at the dispositional level is discussed in this section. Dispositions have been defined as "habits of mind" (Katz & Raths, 1985). Because they are always manifested in context, they are the right conceptual "size"; like the metacognitive skills discussed above, they are neither too specific to be generalized nor too large to get a handle on (Katz & Raths, 1985). The notion of disposition fits well with current approaches to motivation and control that emphasize the role of cognitive-perceptual processes (Ames & Ames, 1984).

Performance and Mastery Dispositions

One of the most prominent strands of research on motivation is that conducted by Dweck and colleagues (Dweck, 1986; Dweck & Elliott, 1983). This research highlights the importance of two motivational dispositions or orientations: Mastery, where the goal is to increase competence, and performance, where the intent is to do well and thus gain a positive judgment of one's competence. There is a structural aspect to the two dispositions in

that each consists of a logically coherent set of cognitions or beliefs. For example, children with a mastery as opposed to a performance orientation ask different sorts of questions prior to undertaking a task (e.g., "What will I learn?" as opposed to "Can I do it?"). They view errors in a different light, seeing them as providing useful information rather than as something to be avoided.

There are attributional differences between mastery- and performance-oriented children, with the former clearly preferring effort over other causal factors when accounting for success or failure. Mastery-oriented children also tend to view teachers in a different light, seeing them as resources or guides in the learning process as opposed to judges or rewarders/punishers. Finally, the standards mastery-oriented children use to evaluate successful learning differ dramatically from those used by performance-oriented children. They are personal and flexible as opposed to normative and immediate. Even if they fail to achieve their goal, mastery-oriented children may experience considerable satisfaction about what they have learned (Dweck & Elliott, 1983).

In much of the literature, it is assumed that mastery and performance orientations are mutually exclusive. Recent work by Ames and Archer (1987), however, indicates that these dispositions may be independent, at least at the classroom level. They used a questionnaire to assess junior high school students' perceptions of the extent to which their classes evidenced one (e.g. "In this class, I work hard to learn") or the other orientation (e.g., "In this class, I work hard to get a high grade"). Surprisingly, ratings on the two scales were uncorrelated ($r = -.03$). Furthermore, mastery and performance orientation ratings were both related to strategy attributions; that is, the tendency to attribute doing well in class to the use of "good study strategies."

Because Ames and Archer operate within a framework that considers mastery to be the most appropriate orientation, they have trouble interpreting this finding. They caution, "It should be noted that we do not know how students interpreted 'good'" (p. 13). They add, "It also appears that strategy is too broad a term and must be defined more specifically for meaningful interpretations to be made" (p. 19). Another way of interpreting these findings, however, is to say that both motivational dispositions can be adaptive, depending upon the learning context (c.f., Biggs and Rihn, 1984).

There are times in the classroom when a performance orientation is perfectly reasonable--when it makes sense for a student to view the academic task "as a demand to be met, a necessary imposition if he or she is to reach some other goal" (Biggs & Rihn 1984, p. 281). If the material is perceived as being uninteresting or meaningless because the learner lacks the prior knowledge necessary to make connections, a surface, reproductive approach may be considered more appropriate (Biggs & Rihn, 1984). Interestingly, the extent to which students adopt either a performance or mastery orientation varies across subject matter domains, at least at the college level.

For example, Biggs (1982) presents data indicating that science students at the undergraduate level tend to evidence more of a "surface" (i.e., performance) orientation to learning compared with their liberal arts counterparts. A similar result was obtained for students at the ninth-grade level when comparing mathematics and English courses (Kirby & Biggs, 1981). A performance orientation may be more adaptive given the way science and mathematics courses are currently organized. This will generally be the case when the emphasis in learning is on the reproduction of seemingly unrelated facts and details.

As Levin (1986) points out, different types of learning strategies are more or less congruent with different types of cognitive purposes (i.e., motivational

orientations). The use of mnemonics, for example, or of certain kinds of test strategies may make sense only in the context of a performance orientation. Apparently, as the above research indicates, students do evidence different learning orientations based on what they bring to a course and their perceptions of what the course demands (Ramsden, 1979). The important point to keep in mind is that both performance and mastery dispositions have their place--and it is important for students to be able to access either one when appropriate.

Organization and Awareness

The relationship between dispositions and cognitive skills is a key organizational issue that has yet to be adequately addressed. While virtually all researchers agree that more than "cold cognition" is involved in doing well in school, few have examined how cognitive and motivational variables connect. As Cullen (1985) points out, work on metacognition has proceeded independently of the work being done on motivation. Cullen's research, focusing on the connection between learned helplessness and strategic thinking in school-aged children, represents an exception.

In one study, involving 90 eight-year olds, separate measures of strategic thinking and persistence on problem-solving tasks were obtained (in this study, withdrawal from the problem situation was thought to constitute evidence of learned helplessness). Cullen's hypothesis was confirmed when a strong relationship was obtained between strategic thinking and high persistence on the problem-solving tasks. Students who had the strategic ability to cope evidenced more of a mastery orientation to learning. This suggests that the more traditional motivational argument (e.g., If students would do it, they could) needs to be turned on its head (e.g., If students could do it, they

would. In other words, they would persist at problem solving if they had the skills that allow them to do so.).

A second study, by Kurtz and Borkowski (1984), also demonstrates a link between strategic thinking and motivational orientation. In this study, first- and third-grade children were trained to use various memory strategies. The researchers found that children who attributed success to effort were more strategic on transfer tasks than those who attributed task outcomes to uncontrollable factors such as task difficulty. Kurtz and Borkowski explained this by saying that children with an effort orientation profited more from strategy training than those with a different orientation.

This research seems to indicate a strong relationship between strategic thinking and motivational orientation. Borkowski, Johnson, and Reid (1987) suggest that motivational beliefs--particularly those relating to causes of success and failure--should be considered part of metacognition. They argue that metacognitive states are more than "information states." "In addition to their cognitive aspect," they argue, "they contain affective and motivational components (e.g., self-attributions about achievement) that can energize or hinder the use of a strategy or skill on a transfer task" (p. 166).

Incongruence between motives and strategies. Including motivational disposition under the rubric of metacognition begs several questions, especially the one relating to how it develops. Furthermore, it is refuted by data presented by Biggs (1984), which shows that strategies and motives need not be congruent. According to Biggs, this is especially true for ineffective students, who frequently make incongruent strategy choices. These students often prefer high-level strategies, which involve a considerable amount of planning and organizing, even though they evidence an "instrumental" motivational orientation.

> If a student decides he or she wants only to pass, then it makes sense to the student (if not to the teacher) to rote learn only those facts and details on which the student knows (or guesses) he or she will be tested (p. 118).

Apparently, more effective students are better able to align their strategic thinking with their motivational orientation; that is, the strategies they select are more consistent with what it is they are trying to accomplish.

One implication from Biggs' research is that ineffective students frequently choose strategies that are inconsistent with their motivational orientation because they lack strategies that would be consistent. This hypothesis is supported by some other work that Biggs has conducted with undergraduate students (Biggs & Rihn, 1984). These students were the mirror image of those described above. Although they evidenced a mastery orientation on a questionnaire developed by Biggs, they appeared to be committed to relatively low-level, reproductive learning strategies. The intervention program designed for these students attempted to foster learning-to-learn skills. It stressed how difficult it is to remember isolated detail unless it is placed in a context of main ideas. Students were taught comprehension-fostering and monitoring skills, such as how to identify and interrelate main ideas. The program was quite successful, in part, according to Biggs and Rihn, because students brought the right motivational "context" to the strategy learning process.

This raises an important organizational issue: Does motivational disposition influence strategy acquisition, or does it work the other way around? The only research found that directly addresses this issue is that done by Vallacher and Wegner (1985, 1987). They have developed an interesting perspective on the relationship between "action" (i.e., skill, strategy) and what they term "action identification," which at the most abstract level has motive dispositional qualities. Their theory is unique in that it suggests how organization and awareness factors interact in the cognitive representation and control

of action. The theory holds that

> Any action can be identified in many ways, ranging from low-level [i.e., strategic] identities that specify how the action is performed to high-level identities [i.e., motives or dispositions] that signify why or with what effect the action is performed. The level of identification most likely to be adopted by an actor is said to be dictated by processes reflecting a trade-off between concerns for comprehensive action understanding and effective action maintenance. This means that the actor is always sensitive to contextual cues to higher levels of identification but moves to lower levels of identification if the action proves difficult to maintain with higher level identities in mind. (Vallacher & Wegner, 1987, p. 3)

Some of the important distinctions they make must be explicated if one is to understand how action identification theory speaks to the issue raised above; that is, how strategic level thinking and motive disposition relate.

Action and action identity. One distinction central to the theory is that between action, or overt behavior, and the cognitive representation of that action, which is termed an "action identity." Any action can be identified in multiple ways. "Reading," for example, might be identified as "looking at words," "understanding main ideas," or "gaining knowledge about things." The relationship between action and action identification is complex; sometimes cognitive representations generate action, and at other times they emerge during or immediately after an act. There is a cyclical relationship between these two phenomena: "Through the intent connection, cognitive representations generate action, and through the reflective connection, new representations of what one is doing can emerge to set the stage for a revised intent connection" (Vallacher & Wegner, 1987, p. 4). An example may help illustrate this relationship.

A student may undertake to prepare for an exam with a performance orientation in mind (e.g., "I'm doing what I have to do to pass the test"). As he engages in the strategic behavior thought to be consistent with this intent--underlining important sections of the text, jotting down reactions to what he's

reading, attempting to relate new material to what he already knows--the student may find that he is going beyond the narrow requirements of the task, even to the point of checking out additional books from the library. Because, the theory states, people prefer to think about their acts in the most encompassing way possible, the individual is now receptive to new ways of conceptualizing his behavior. Conditions are ripe for a mastery characterization to emerge (e.g., "I'm becoming more competent in this subject"), an action identity that may be suggested by a fellow student or the teacher.

On the other hand, assume the student has trouble implementing his study strategy--finding it impossible, for example, to relate new information in the text to knowledge he already possesses. In this situation, action identification theory predicts, the student may lose sight of his original intent and move to lower level ways of thinking about the action. Underlining could become the focus as the person highlights every line of text with his yellow marker. It is not uncommon to encounter this sort of mindless behavior even in college students (Devine, 1981).

A couple of points need to be made about this analysis. First, Vallacher and Wegner (1985) assume that the various ways of identifying an action are systematically related to one another in organized cognitive representations called "identity structures." An identity structure is a hierarchical arrangement of action identities, consisting of lower level, more detailed representations as well as higher level, more abstract ways of thinking about the action. The higher level/lower level distinction is conveyed in everyday language through the use of relational terms like by. Thus, for example, one becomes more competent in history by comprehending the history text; one comprehends the history text by doing lots of things--by first skimming each chapter to get the main ideas, by anticipating certain questions that may arise as one

reads each chapter, by paraphrasing what one has just read; one skims each chapter, in turn, by reading the topic sentence in each paragraph; and so on. As is evident in this example, each successive action identity is considered lower level or more detailed.

A second important point is that strategic or "how to" ways of conceptualizing actions are logically connected to more abstract "why" or "with what effect" types of identification. The latter type of goal-oriented characterizations emerge from reflections about strategic level activity when two conditions are met: First, one has sufficiently mastered the strategy or action. Second, a compelling higher order identity comes to mind or otherwise is made available to the individual. Thus, one of the principles of action identification theory is that people move toward higher levels of action identity only when an action can be properly maintained in terms of its existing or prepotent identity. A student is not apt to characterize his learning activity as either mastery- or performance-oriented if he is unable to perform the requisite strategic level action; difficulty in this regard will naturally force him to attend more to strategic detail.

Once the activity has been mastered, however, continued attention to strategic detail may be counterproductive. Support for this notion can be found in a recent review by Palincsar, Stevens, and Gavelek (in press). Puzzled by the differential effectiveness of reciprocal teaching in one of their inital, teacher-implemented studies, these researchers came up with an interesting interpretation of the results: Although all students had learned the requisite skills (i.e., summarizing content, asking meaningful questions), some benefited more from the training than others. Those who registered the greatest gains in comprehension were taught by teachers who viewed the reciprocal teaching technique as a means to an end (i.e., understanding), not as an end in and of

itself. Presumably, these teachers shared this sense of what the enterprize was all about with their students--and this more abstract understanding contributed to students' ability to make effective use of the strategy. Further insight about these issues is provided by Wegner and Vallacher (1983).

Maintenance difficulty. Wegner and Vallacher identified five factors which contributed to "maintenance difficulty;" that is, to the difficulty one encounters in carrying out an activity. These factors are relative difficulty ("how difficult is the action?"), complexity ("how many different ways are there to do the action?"), familiarity ("how familiar are you with the action?"), enactment time ("How long does it take to do the action"?), and learning time ("how long does it take to learn to do the action?"). A sample of undergraduate students rated 35 actions on each of these dimensions, using a five-point scale defined by appropriate descriptors at each end (e.g., "not difficult" versus "very difficult" for the difficulty dimension). A variety of actions were sampled, including "making a list," and "climbing a tree" (thought to be relatively simple actions), and "taking a test" (thought to be a more difficult and complex undertaking).

Not surprisingly, actions differed dramatically in terms of how they were rated on the hypothesized indicators of maintenance difficulty. More importantly, there was a significant negative relationship between measures of maintenance difficulty, obtained by summing ratings across scales for each action, and indices thought to reflect each action's characteristic identification level. This second set of measures were obtained from a separate sample of 274 undergraduates asked to endorse one of two alternative identities for each of 25 actions; one choice represented a lower level identity (e.g., "answering questions" for the action of "taking a test"), the other, a higher (e.g., "showing one's knowledge" for the same action).

The level at which an action is prototypically identified varies as a function of how difficult the action is to maintain: "The more complex or time-consuming an action, the more one tends to think about the action in terms of its how-to components, and presumably this relationship is in the service of effective maintenance" (Vallacher & Wegner, 1985, p. 97). The fact that knowledge of action develops hand in hand with mastery of action may account for why performance dispositions tend to predominate at the elementary school level (Anderson, 1984). Presumably, the strategies that logically relate to such an orientation are more easily mastered than those that play more of a competence-fostering role.

This may be especially true of surface level approaches that rely heavily on memorization (Biggs, 1984; Levin, 1986) or the simple completion strategies identified by Anderson (1984), where the goal is to finish the assignment regardless of whether or not the answers make sense. Because actions such as these are more easily "maintained" in the classroom, high-level identities associated with the actions are more likely to emerge. (It may also be the case that the identity conditions surrounding actions in the classroom are primarily performance-oriented. Performance evaluation tends to be highly visible at the elementary level [Rosenholtz & Simpson, 1984].)

Conflict between indicators. Ordinarily, the various maintenance indicators (i.e., relative difficulty, complexity, familiarity, enactment time, and learning time) work together to determine the level at which an action is maintained. The covariation is far from perfect, however. There are times when indicators are in conflict. In such situations, according to Vallacher and Wegner (1985), the indicator promoting the highest level identity tends to prevail. This results in an individual adopting an identity that is inappropriate or otherwise less than optimal for effective action maintenance. According to

Wegner and Vallacher (1983) two kinds of situations account for most of these anomalies: Actions that appear easy to perform but that are quite new to the person, and actions that, while seeming natural or familiar, are very difficult to carry out. In both cases, there may be a press toward high-level identity even though the action has not been fully mastered at a more detailed, strategic level.

This is speculative, but performance strategies, especially those involving the use of mnemonics, may be susceptible to the first kind of misjudgment. There is an easy but unfamiliar quality about many of the mnemonic techniques. As an example, consider Bransford et al.'s (1980) strategy for remembering facts about arteries:

> The fact that arteries are thick could be remembered by forming an image of a thick, hollow tube that flashes "artery." The fact that arteries are elastic could be remembered by imagining that the tube is suspended by a rubber band that stretches and contracts. (p. 96)

Such strategies strike students as being fairly easy--and also fairly novel. Because of the novelty or unfamiliarity, enactment of strategies such as these requires careful attention to its how-to components; unfortunately, the fact that it appears easy to perform may lead students toward a high-level identity (i.e., "I'm learning about anatomy") that would not be effective in maintaining the behavior. The opposite argument could be made in the case of mastery strategies such as those taught through reciprocal teaching (Palincsar & Brown, 1984).

As Brown (1985b) emphasizes, one of the strengths of the reciprocal teaching approach--and of other successful attempts to teach executive control skill--is that "the strategies are always modeled in appropriate contexts, not as isolated, separate skill exercises" (p. 17). Collins et al. (in press) use the term "situated learning" to describe this characteristic of successful

programs. Because the processes have such face validity, they may appear quite natural or familiar to many students. Once again, however, there is a chance for conflict between the familiarity and difficulty indicators. Sensitivity to the action's seeming familiarity (i.e., "I do this when I read") may promote a level of attempted maintenance which is at odds with where the person actually is in terms of the mastery sequence. As in the previous case, low- and high-level identities will not be integrated together in a single identity structure. This may lead to incongruent strategy-motive combinations.

According to Biggs (1984), incongruent strategy choices are more typical of low-achieving students, a finding which is consistent with Vallacher and Wegner's (1985) notion that action mastery is a precondition for optimal, high-level action identification. Dispositions that are strategically "grounded" in this way, one might hypothesize, allow for the kind of flexible, mindful involvement in the learning process typical of the truly empowered student. This student would possess sufficient skill to maintain, when appropriate, either a mastery or performance orientation to learning, or some combination of the two. When difficulties are encountered in the classroom, these high-level identities could be used to call to mind, in a very self-conscious way, the strategies that might allow the student to resolve the difficulty. (In the case of mastery-related strategies, this is more likely to occur early and late in the learning process [Siegler, 1987]).

Summary. Although action identification theory has not been used to explicate the relationship between strategic thinking and motive disposition prior to this time, it is obvious that the theory addresses many of the issues raised by cognitive psychologists. The theory suggests that organization and awareness factors interact to influence dispositional thinking. It indicates that our thinking about an act--even a complex strategic act--changes as we gain

mastery over the act. We lose sight of the details and a higher level, more abstract way of representing the act comes to the fore. Thus, as one becomes more strategically proficient, issues of motive and disposition become more relevant.

Generally, there is congruence between strategy and motive, although there are occasions when the two are not well matched. Learning strategies that appear easy to perform (i.e., mnemonic strategies), but that require careful attention to detail for successful maintenance, may lend themselves to inappropriate or incongruent high-level identity; the same fate may befall complex strategies that appear quite familiar, perhaps because they are taught in a natural learning context (i.e., comprehension monitoring). In either case, students may develop an abstract way of representing action that cannot be maintained, and that, in fact, is logically unrelated to the outcomes they are likely to achieve with the action. The relationship between strategies and dispositions appears to be more interactive than hierarchical, however. As Biggs and Rihn's (1984) work suggests, motive dispositions may facilitate the acquisition of additional strategies--providing the strategies are perceived as congruent with the dispositions. It appears, then, that organization and awareness factors interact in complex ways to influence dispositions.

Implications for Instruction

In this final section of the paper, I will elaborate on some of the instructional implications alluded to in earlier sections. Specifically, I will discuss three characteristics of instruction that appear to facilitate the development of accessible knowledge, strategy, and disposition on the part of students. These characteristics should be considered somewhat speculative. As Leinhardt (1988) points out, there is a dearth of research examining the

teaching and learning of content from a holistic perspective--starting with teachers' content, how teachers organize curricula to pursue content goals, guide classroom interaction, and assess students' understanding of important ideas. More definitive statements about the type of teaching that promotes access in students will undoubtedly emerge from such research.

Based upon what we now know, however, it is obvious that the commonsense view of teaching must be reformulated. This view is based on an "absorptionist" theory of learning--that is, a belief that individuals learn by absorbing new information (Romberg & Carpenter, 1986). The teacher's task, according to this view, is to transmit knowledge to students. Although considered a straightforward process, teachers nevertheless are thought to differ in the skill with which they carry it out. The good teacher is one who has developed a repertoire of explanations for the same idea, the assumption being that if one approach doesn't work, another will (Schoenfeld, 1988). Paradoxically, in this view of teaching, both teacher and student play relatively passive roles, the teacher as explainer, the student as repeater (Lockhead, 1985). Doyle (1986), Cohen (1988), and others document the vested interests of both students and teachers in maintaining this status quo.

Although the transmission view of teaching is the most common, what Bereiter (1985) terms the "nonspecific" approach to teaching runs a close second. The focus in this type of teaching is on general instructional processes (e.g., inquiry) thought to exert a profound influence on learning. The nonspecific approach has its adherents, particularly in science. It also has its critics. Anderson and Smith (1987), for example, have expressed concern about the excessive emphasis placed on process in so-called discovery approaches to science. They emphasize that process skills, such as observing, measuring, and making inferences, which form the core of discovery-oriented curricula in

science, were developed as a means to an end--the end being a better understanding of how the world works. In many activity-based programs, Anderson and Smith argue, there is too little focus on conceptual understanding. As a result, students often rely on their own misconceptions to interpret activities and experiments.

Bereiter (1985) compares the nonspecific approach to teaching to an exercise and diet program in health. It deals with factors that are, in a sense, one step removed from the content learning process. He prefers an alternative that falls somewhere between the two extremes discussed above. In this middle-ground approach, instructional strategies function more like enzymes and hormones: They play a specific role in learning, even though their influence is indirect. The instructional interventions are indirect because the goal is to get students to construct their own knowledge. As Resnick (1987) puts it, the task is "to develop a psychology of instruction that places the learners' active mental construction at the heart of the instructional exchange" (p.47). The teacher's task is to create conditions that allow students to construct knowledge that is both powerful and "correct" (i.e., consistent with disciplinary knowledge). How might one characterize such interventions, which are more likely than traditional approaches to promote transfer in in students? Current research points to three attributes that appear to be of central importance in attempts to teach for access. The instruction should be <u>focused and coherent</u>, it should be <u>negotiatory</u> in its interactive style, and strongly <u>analytic</u> or <u>diagnostic</u> on the teacher's part.

<u>Focus and Coherence</u>

Support for the importance of focus and coherence in teaching for access comes from several sources. First, there is the expert-novice research, which

indicates that the expert's knowledge base is organized around a more central set of important ideas or understandings than the novice's (see the "key ideas" section above). By implication, expertise in students may be best fostered when school curricula carefully attend to a network of central ideas or understandings derived from the disciplines. A second, more direct source of support for this notion is the growing body of research relating teachers' subject matter understanding to students' subject matter understanding. Until recently, this kind of research was virtually nonexistent (Shulman, 1986), partly because of the focus on generic teaching processes such as classroom management (Shulman, 1987), and partly because it didn't seem profitable. As Ball (in press) points out, earlier research had failed to demonstrate any consistent relationship between student achievement and teacher knowledge in various subject matter domains; however, this research relied on indirect measures of teacher subject matter knowledge, such as the number of college-level courses taken in a particular domain.

Thanks in large part to the recent emphasis on conceptual understanding and higher order thinking in students, particularly in mathematics and science, the role of teacher content knowledge is being reexamined. This research is demonstrating that there <u>is</u> a clear relationship between what teachers know about content and the depth of understanding they are able to promote in students. This relationship is far from perfect; other variables influence the extent to which teachers utilize their content knowledge. As Ball (in press) argues with regard to mathematics, "A teacher who does understand the role of place value and the distributive property in multiplying large numbers will not necessarily draw upon this understanding in her teaching, for her ideas about learners or about learning may intervene." Teachers with the same level of conceptual understanding may teach differently depending upon their educational beliefs.

Nevertheless, a good grasp of what ideas are most central to the discipline, how they relate to one another, and how they best can be represented, bears a necessary if not sufficient relationship to conceptual level teaching.

Research conducted by Lee Shulman and his colleagues at Stanford provides support for this notion. Steinberg et al. (1985), for example, intensively followed four secondary mathematics teachers in their first year of teaching. Based on interview and observation data, they developed detailed case studies of these teachers that focused, in particular, on the relationship between content knowledge and teaching practice. The two teachers who had the surest grasp of mathematics--being able to identify central ideas and relate concepts--were also the most "conceptual" in their approach to teaching. They were more inclined to explain why certain mathematic procedures do or do not work, to stress central ideas, and to engage the students in more problem solving activity. This ability to focus on the big picture is characteristic of expert teachers in other subject matter domains as well (Gudmundsdottir & Shulman, 1987). Other case studies document the relationship between content knowledge and conceptually oriented teaching.

Leinhardt (1988) did detailed analyses of one expert second-grade teacher's subtraction lessons. In this study, teacher subject matter knowledge was examined in a novel way: Eight lesson videotapes were transcribed, and each conceptual statement made by the teacher was analyzed using a mapping technique similar to Novak and Gowin's (1984) discussed earlier. Interestingly, the same set of five key ideas were found in each of the eight lesson diagrams; an example is the notion that certain subtraction problems--called "foolers" because the top number in the ones place is smaller than the bottom--require different treatment. This teacher, who was successful in getting students to understand the mathematical basis for regrouping, had focused her instruction

on a limited set of major ideas. Lampert (1986) provides another case study example of the importance of conceptual focus in teaching mathematics for understanding.

Support for the importance of focus and coherence also comes from cross-cultural studies of mathematics teaching and learning. Stigler and Perry (1988), for example, are comparing the way mathematics is taught in Asian and American classrooms. Although pointing out the preliminary nature of their findings, Stigler and Perry cite evidence supporting the contention that the Asian mathematics curriculum is more focused and coherent than the American. Asian teachers appear to provide students with more opportunities to make connections across elements or segments of mathematics' lessions: "In Chinese classrooms, and in Japanese classrooms to an even greater extent, we see teachers providing explicit markers to aid children in inferring the coherence across different segments within a lesson, and across different lessons" (pp. 42-43).

This attempt to provide coherence is not as evident in classes observed in the United States. Stigler and Perry speculate that it may be easier for Asians teachers to make connections of this sort because their lessons tend to be much more focused than those observed in our own country. It is not uncommon, they report, for teachers in Japan and Taiwan to devote an entire 40-minute mathematics class to working two or three problems (i.e., discussing alternative solutions, etc.). These differences in coherence and focus may play an important role in accounting for the Asian student's mathematical superiority vis-a-vis the American.

One final bit of evidence for the importance of focus and coherence comes from an exciting new study by Newman and his colleagues (1988). Their research examines factors that impede and facilitate higher order thinking at the high

school level. The focus in particular is on high school social studies classes. Of particular relevance here is the instrument they recently developed to measure the amount of "thoughtfulness" evident in classroom discourse. Two of the six scales on this instrument reflect focus and coherence concerns: One assesses the extent to which discourse is characterized by "sustained examination of a few topics rather than superficial coverage of many;" the second scale, titled "substantive coherence and continuity," gets at the extent to which ideas are pulled together or integrated during discourse.

Negotiation

Several cognitive psychologists, especially in mathematics, have used the term "negotiation" to describe the kind of interaction that occurs between teacher and student and student and student in classrooms where teaching for access is the norm (Cobb, Yackel, & Wood, 1988, in press; Schoenfeld, in press; Steffe, 1988). Use of this term highlights the social nature of the learning process, particularly if one focuses on one of at least two possible definitions. According to this first definition, negotiation is a process of reasoning together; when one "negotiates," one confers with others in order to reach agreement on some important matter. This definition fits well with the dialogic nature of conceptual learning; the importance of discourse processes in promoting conceptual level understanding and higher order thinking is becoming increasingly apparent in the research literature (Brophy, in press).

This definition misses the mark in another way, however. It suggests that knowledge can be created through consensus or a type of bargaining process in the classroom. This gets at an important epistemological problem: Is knowledge historical artifact or universal truth? The straw man position on either side of this issue has us, on the one hand, haggling over truth, and on the

other, accepting the voice of authority. It is possible, however, to look at the problem from a different vantage point.

Cobb, Yackel, and Wood (1988) suggest combining psychological and anthropological perspectives. Individuals construct their own reality, but this reality must be consistent with that shared by members of the disciplinary community if one is to participate in the discourse of that community. One goal of education is to acculturate students into the various disciplinary communities. Members of these communities share certain beliefs: for example, beliefs about what constitutes a plausible argument in the context of a discipline like mathematics or science. These institutionalized beliefs constitute disciplinary knowledge. Because the teacher's task is acculturation--which involves not only intellectually challenging the child but also seeking to "shape" the child's knowledge in certain ways--a fair amount of tension is inherent in the teacher's role. Again, speaking of mathematics, Cobb et al. assert, "It is the tension between encouraging students to build on their informal ways of knowing and attempting to teach them the institutionally sanctioned formal knowledge of codified academic arithmetic that gives rise to the paradox of teaching" (p. 3).

Negotiation in the classroom, then, involves more than reaching agreement on important matters; as the above comments suggest, it also involves moving students in a certain direction (i.e., toward the view of reality shared by those in the disciplinary community). Defining negotiation as a "bargaining process" doesn't get at this goal-directed aspect of teaching. Fortunately, there is another definition which better captures this characteristic of instruction: To negotiate also means to "overcome obstacles skillfully" (i.e., as in "carefully negotiating the winding road"). When two conditions are met, this aptly characterizes teaching for access: First, under the rubric of

obstacles are included variables such as misconceptions or faulty reasoning that interfere with students' knowledge acquisition. Second, the process of overcoming these obstacles is viewed as a collaborative enterprise, shared by both students and teachers. The teacher's role, then, is akin to a guide's in helping students traverse new cognitive territory, pointing out--and working with them to overcome--potential obstacles to understanding.

The definition of teaching as the skillful, and collaborative, overcoming of obstacles contrasts with the traditional view. It represents a "cross-country" view of knowledge acquisition. Thus, according to Henry Pollack, most people think that acquiring expertise in a subject like mathematics involves carefully following a well-marked course: "Mathematics, as we teach it, is too often like walking on a path that is carefully laid out through the woods; it never comes up against any cliffs or thickets; it is all nice and easy" (cited in Lampert, in press-a).

Pollack prefers an alternative view. According to this view, it is common and desirable for students to encounter obstacles as they attempt to negotiate the mathematical terrain. Not surprisingly, teachers who play the role of guide by pointing out obstacles to students, probing the limits of their understanding with difficult cases or "entrapments" (i.e., questions designed to snare students into agreeing with certain erroneous ideas), frequently are viewed by students as hinderers and not helpers in the learning process. Teachers will feel comfortable with this role only if they view uncertainty or conflict as an important, growth-producing commodity. There is evidence to show that teachers who embrace such a view are much better at fostering a strategic, mastery-oriented approach to learning (Dweck & Bempechat, 1983).

As indicated above, the teacher, as a guide, is expected to do more than point out potential obstacles to understanding. He or she is also expected to

work collaboratively with students to help them overcome these obstacles. In playing this second role, the importance of having a cognitive map of the sort discussed in the previous section becomes immediately apparent. The teacher can be an effective guide only if he or she has a good sense of direction; not having a sure grasp of the cognitive territory one is to traverse puts teachers in the position of the "blind leading the blind." Teachers need to know where their instruction is heading; not, as Lampert (1988) puts it, "in the linear sense of one topic following another, but in the global sense of a network of big ideas and the relationships among those ideas, and facts, and procedures" (p. 163).

As I argued in the previous section, having this sort of in-depth knowledge is necessary but not sufficient in equipping teachers to teach for access. One of the most important negotiatory skills for teachers appears to be that of structuring classroom discourse to promote knowledge organization and awareness in students. Unfortunately, not much is known about how to do this at the present time. As Corno (1988) and Noddings (1985) point out, the cooperative learning techniques developed thus far, which stress the importance of group incentives and grades, seem most appropriate for lower level, achievement test outcomes; because they stress performance, these techniques may in fact reduce the likelihood that reflective dialogue will occur (Corno, 1988).

According to Roby (1988), it is the dialectical aspect of discourse that promotes student understanding. This aspect concentrates on articulating and contrasting student and teacher opinions. Unfortunately, Roby argues, much of what passes for discussion in classrooms is really "quasi-discussion." It lacks the reflective interaction of dialectical discourse. Quasi-discussions take two forms. One type, dominated by the teacher, follows a question-answer format; there is little opportunity for exchange of ideas. The other type is

termed the "bull session." Here, students and their milieu dominate the topics of conversation; the rambling and uncoordinated discourse compares unfavorably with the purposiveness of dialectical discussion. Unlike the bull session, where there is a rhetorical winner and loser but no real attempt to resolve issues, those engaged in dialectic discussion seek common understandings:

> Opposing views become alternatives to be explored rather than competitors to be eliminated. Consensus on a large scale is not too much to hope for. The initial sense of rightness about one's own answers merges into a sense of rightness about the process which scrutinizes all answers. (p. 173)

Dialectical discussions make use of a number of rhetorical devices, such as the "inviter" (i.e., "Would you tell us about it?") or the "prober" (i.e., "How has your view shifted from the opinion you gave earlier?")(Roby, 1988). One of the most important is the "parallel," which highlights similarities and differences. One type of parallel, for example, has students personalize academic problems by putting themselves in someone else's situation (i.e., "What strategy would you have followed had you been General Washington?"); other types of parallels are more explicit in getting students to compare and contrast different viewpoints. By getting students to carefully examine parallels between their own viewpoints and those of others, the teacher educates students to the importance of connectedness in learning (Barnes, 1975).

In keeping with the negotiation metaphor, teachers play a different role in dialectical discussion. They function, in part, like moderators of discussion, facilitating student-student interaction and utilizing reflective or sustaining feedback to enhance the quality of the discussion (Klinzing & Klinzing-Eurich, 1988). They also provide critical feedback to students regarding the substance of their contributions. All of the above, of course, presupposes that teachers value, and take seriously, the contributions made by students.

Valuing student contributions is the first requirement for successful group work according to Barnes (1975). It may form the basis for all genuine communication between teacher and student. Uhlenbeck (1978) asserts that it is difficult to exaggerate the importance of the hearer assuming some level of rationality on the part of the speaker: "The hearer always takes the view that what the speaker is saying somehow makes sense" (p. 190). This does not mean, however, that teachers should accept uncritically everything that students say--particularly when they evidence flaws in their thinking, or serious misconceptions that represent obstacles to understanding. Such mistakes need to be dealt with in as objective a way as possible. One way to do this is to depersonalize the mistake: Get students to view errors as natural, even useful, concomitants of learning rather than as occasions for embarrassment or shame (Dweck & Bempechat, 1983).

The distinction made earlier between the two types of "negotiation" is relevant here. Prior to engaging in collaborative, problem-solving activity (one definition), it is considered helpful for participants to reach some consensus about the nature of the undertaking (the other definition). As a result of this negotiation process, individuals can develop an appreciation for each other's roles and responsibilities. They also can establish the norms of interaction that will govern how members of the group relate to one another. This process is particularly important in the classroom (Cobb et al., in press). Agreeing on norms that minimize risk may be a necessary, if not sufficient, condition for collaboratively coming to terms with important impediments to understanding.

The outcome of the first type of negotiation process (i.e., the ground rules for discourse) strongly influences subsequent attempts to engage in the second type. Lampert's work (1987) supports this contention. As Lampert

suggests, it may be that students need to learn that is legitimate to have a meaningful discussion about content before they can learn from the discussion. Cobb et al. (in press), in their case study of a constructivist mathematics teacher, comment on the "dual structure" of classroom discourse. They argue that students in the classroom they observed were able to talk about mathematics in ways that facilitated understanding because norms that make such talk possible had been carefully negotiated at the beginning of the year. In getting students to adhere to these norms, the teacher was very direct in her interventions.

For example, in one situation where a child had inadvertently been put on the spot in front of the class, the teacher commented, "It's all right. Boys and girls, even if your answer is not correct, I am most interested in having you think. That's the important part. We are not always going to get answers right, but we want to try" (Cobb et al., in press). In other words, the teacher-led "talk about talking about mathematics" established a context conducive to collaborative problem-solving on the part of the students.

Lampert (in press-b) also stresses the importance of establishing certain ground rules for classroom discourse. In her own mathematics teaching at the elementary level, she very consciously models patterns of discourse that parallel those used by scholars in the discipline. In working on problems, students are expected to recount their own reasoning processes and to analyze those of others. Lampert is quite particular about the language students use when they engage in this sort of discourse. When making assertions, for example, students are encouraged to say "I think" rather than "It is" or "I know:" "Saying 'I think' rather than 'It is' protects the student from associating his or her sense of self with an assertion that is later revised because it has been proven wrong" (p. 32).

Analysis/Diagnosis

In addition to the attributes talked about above, teaching for access can also be characterized by its highly analytic or diagnostic nature. This is less true of more traditional approaches to teaching. Student assessment has always been considered an important, but not primary, component of instruction (Putnam & Leinhardt, 1986); given the kinds of constraints under which teachers operate (e.g., dealing with 20 to 30 students), they appear to do a credible job of evaluating learning outcomes. Research shows, for example, that most teachers can accurately predict how their students will perform on individual test items, especially those items that are cognitively less complex (Coladarci, 1986). In more constructivist approaches to teaching and learning, however, the assessment--or more precisely, the analysis or diagnosis--of student learning occupies an absolutely key position. Many researchers argue that analysis of student learning should be the basis for instructional decision making; clearly, it is now viewed as a more integral part of the teaching process.

As will become obvious, the need to analyze constantly what students are learning places a special burden on the teacher. To carry out this task, teachers need access to both general and specific knowledge: knowledge about learners and their characteristics, knowledge about content and curricular materials, pedagogical knowledge, and so forth (Shulman, 1987). Arguably, the most important general knowledge for teachers to possess is that relating to the learning process. Studies show that teachers who subscribe to more of a constructivist view of learning attach greater importance to student input as a source of information about thinking than do teachers who embrace more of a traditional, absorptionist perspective. Thus, Peterson, Fennema, Carpenter, and Loef (in press) compared constructivist and nonconstructivist teachers in mathematics; the former attended more to what students did and said during

problem solving and thus had a more sophisticated understanding of the strategies their children used to solve simple word problems. Preliminary analysis of data gathered at the National Center for Research on Teacher Education also provides support for the importance of knowledge about learning; these data indicate that teachers transfer changed views about learning in one subject matter domain to other domains (D. L. Ball, personal communication, September, 1988).

The best way to enhance assessment capability may be to provide teachers with fairly detailed information about children's thinking in specific subject matter domains. Those who stress the importance of this specific type of knowledge emphasize the need to effect a match between the intellectual resources children bring to a particular learning task and the cognitive demands of the task (Romberg & Carpenter, 1986). Teachers can make intelligent decisions in this regard, the argument goes, only when they fully appreciate the developmental course of children's thinking in the subject matter domain. There is some support for this notion. Cognitively Guided Instruction (CGI), an approach to elementary mathematics developed by researchers at the University of Wisconsin, approaches the assessment issue from this perspective (Carpenter, Fennema, Peterson, Chiang, & Loef, 1988).

Rather than provide teachers with a program of instruction, CGI first familiarizes teachers with research on the development of children's thinking about addition and subtraction. (One of the purposes is to dispel the notion that number facts and computational skills must be mastered before children can solve word problems.) In a recently completed study, teachers were encouraged to use this newly acquired information about children's invented strategies to design their own programs of instruction. As expected, the month-long, summer treatment phase of the study strongly affected teachers' orientations toward

assessment; follow-up observations revealed that the experimental teachers, compared to the controls, elicited, and were more attentive to, students' explanations of their problem-solving strategies. Not surprisingly, researchers also found that the experimental teachers were more accurate in predicting the strategies their students would use to solve problems and generate number facts.

A third approach to getting teachers to attend more to student cognitions during mathematics has been utilized by Cobb et al. (1988). These researchers deliberately chose not to discuss models of early number learning with teachers during the first part of the study, arguing that teachers would not fully appreciate the relevance of these models to classroom practice at that point. Instead, the focus of the one-week summer institute was on classroom practice; this continued to be a major focus during the weekly, small-group follow-up phase of the study. These meetings addressed teachers' pragmatic concerns, such as how to involve children in mathematical discussions. The goal in dealing with issues of this sort was to get teachers to focus less on management concerns and more on the innovative mathematical activities that they were trying to implement.

It was thought that these changes in instructional practice would create a context that would make relevant the additional information about students that the researchers wanted to supply: "It was when the teachers began to use the problem-centered activities and encountered problematic situations that they came to realize that they had an inadequate knowledge of children's mathematics activity and actively wanted to learn about it" (Cobb et al., 1988, p. 30). This approach to developing analytic skills in teachers is less direct than the Carpenter et al. (1988) approach. Analysis of student learning is a by-product

of getting teachers to rethink fundamentally their orientation to teaching a particular subject.

When teachers adopt a different set of instructional goals, it is hoped, they will find themselves attending to different kinds of student behavior. There is some indication that the process does unfold in this way. Putnam (1987), for example, found that teacher assessments were very much linked to the goals they pursued. Thus, the teachers in his study who favored an algorithmic approach to teaching addition focused more on students' ability to recite and carry out steps of the algorithm; teachers whose goals were more conceptual tended to emphasize student understanding of procedures--as reflected, for example, in the ability to link procedures to manipulatives.

Newman and his colleagues (1988) also observed a relationship between teachers' instructional goals--in this case, for high school social studies--and the kinds of behavior they attended to on the part of students. Teachers who placed the highest priority on student thinking were the most articulate when it came to discussing what it involved. When asked to distinguish their best thinkers from other students, for example, these teachers' comparisons were lengthier, more detailed, and more elaborate than those provided by teachers who emphasized more traditional goals in the content domain.

As this discussion indicates, there are a number of ways to develop analytic skills in teachers. Each of the above has its adherents. Each could complement the other; a program aimed at getting teachers to be more analytic during instruction could emphasize all three--exposing teachers to the basic tenets of constructivism, providing teachers with detailed information about children's thinking in various subject matter domains, and encouraging teachers to experiment with, and carefully observe the effects of, different kinds of

novel activities and curricular materials. This might exert a cumulative effect that none of the approaches, taken individually, could match.

Regardless of how one fosters analytic or diagnostic skills in teaching, however, there is a growing consensus that such skills are an essential component of teaching for access. Being analytic goes hand in glove with each of the other two attributes of this type of teaching. As Lampert (in press-a) points out, conjectures about student thinking should be part of the lesson planning process. Knowing what sorts of concepts or understandings are likely to be troublesome for students is important data for teachers to have when setting content priorities. Because the focus in this approach to assessment is less on the production of correct responses and more on the process of reasoning that underlies the responses, student learning is best analyzed in an interactive context. Thus, it is important that the norms of interaction in the classroom actively encourage the public sharing of thoughts.

Summary

The student's ability to access or utilize information in potentially relevant situations is of central importance in education. If the knowledge, skill, or disposition students acquire cannot easily be accessed when needed, very little has been accomplished. As viewed here, access is largely a function of two important factors: organization and awareness. These factors play slightly different roles depending upon whether knowledge, skill, or disposition is involved.

In the knowledge base category, organization is equivalent to connectedness. Connections between key concepts (i.e., ideas) and procedures provide the glue that holds the cognitive structure together; the adequacy of this structure, in turn, determines the accessibility or availability of information

at a later time. One implication of the "key ideas" notion is that teachers should be extremely selective in terms of the ideas or concepts they present to students, making sure that depth of understanding in a subject matter domain is not sacrificed in the interest of coverage and that the ideas selected have maximum potential for developing knowledge rich in relationships and "generative" in the sense of being useful in understanding a range of interesting phenomena. Teachers could foster connectedness by deliberately comparing and contrasting each new concept with those presented previously. In the knowledge base section, the importance of making representational links and of getting in touch with students' informal knowledge was also discussed.

Developing connectedness is viewed as one important way to enhance knowledge accessibility; developing reflective awareness in students is seen as another. Reflectivity is enhanced when students are encouraged to articulate their own thoughts. Dialogue and discussion make students more aware of what they know and do not know; confrontation with alternative views further exposes the limitations in one's own thinking. Another way to develop reflective awareness in students is to "conditionalize" knowledge in various ways--that is, to demonstrate to students how the information can be used in various situations. Knowledge relevant to problem solving enjoys an advantage in this regard. Presumably, the conditions of its use can be more precisely specified.

In the strategic category, organization and awareness factors are also thought to play an important role in mediating access to potentially relevant information. The key organizational issue at this level appears to be how to strike the right balance between specificity on the one hand and generalizability on the other. Specific strategies are more teachable and also more powerful in the sense that, when accessed, they lead to a certain result; the problem with specific strategies, of course, is that they do not readily

transfer to new, potentially relevant situations. General strategies, however, although more versatile, are more difficult to teach. Strategies of the middle range, such as those advocated by Collins et al. (in press), appear to represent the best solution to this dilemma. The importance of reflective awareness or metacognition as a factor influencing strategy transfer has been demonstrated in a number of informed training studies. As part of the effort to conditionalize strategy use, students should be made aware of how factors such as the nature of the material to be learned or the kind of outcome they wish to achieve can influence the sort of strategy they select.

Two key motivational orientations were discussed in the dispositions section: a performance orientation, the intent of which is to get the job done as quickly and painlessly as possible, with learning serving as a means to an end and not an end in and of itself; and a mastery orientation, the intent of which is to increase competence, to become more knowledgeable about or skillful at something. Both dispositions lend themselves to strategic thinking, but the kinds of strategies are markedly different. The nature of the relationship between strategy and disposition was a central concern in this section of the paper.

Research suggests that there may be an intimate relationship between these two variables: If students are to develop a mastery orientation to learning, they must be strategically equipped to learn on their own. Complex learning strategies such as planning, monitoring, and checking appear to go hand in hand with a mastery orientation toward learning. If this is true, the best way to develop reflective awareness at the dispositional level is to render strategic action more familiar, automatic, and generally easier to perform. According to "action identification theory," individuals think differently about an act when they need no longer focus on strategic detail; they are receptive to more

abstract, dispositional ways of representing the act. How teachers characterize learning activities (i.e., the emphasis assigned to learning versus performance aspects of tasks) thus exerts a strong influence on students' motivational orientations.

As this discussion indicates, instruction is a much more complex process when access is the goal. This type of teaching requires more knowledge and skill on the part of teachers than is currently the norm. As sketched out in the Holmes Group (1986) report, a document authored by educators dedicated to the reform of teacher education, those who teach for access must possess considerable subject matter and pedagogical expertise: If students are to develop networks of knowledge, teachers need a firm grasp of the most important ideas in each of the subject matter areas they teach. They should have at their command detailed information about the developmental course of children's thinking in those content areas. They should know how to foster various learning-to-learn strategies, and how to equip students with sufficient metacognition so that they can exercise judgment about the use of those strategies. This also involves developing an awareness in students of when certain motivational orientations are more or less appropriate--and grounding those orientations in strategies that are congruent with the orientations. In short, it involves thinking of the child as a total cognitive being, one who--when empowered--has access to a full range of intellectual resources and thus can respond proactively as opposed to reactively in various in-school and out-of-school contexts.

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